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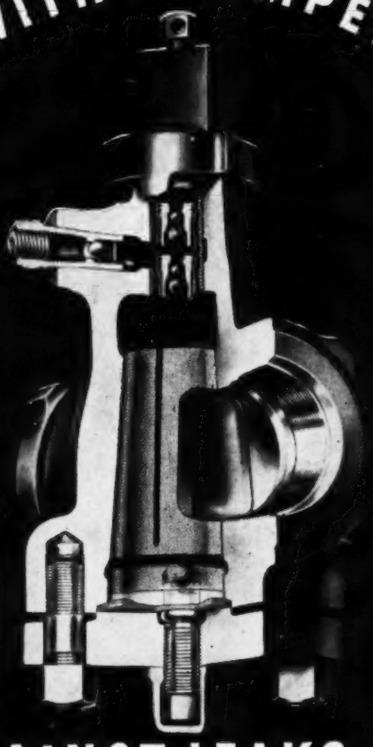

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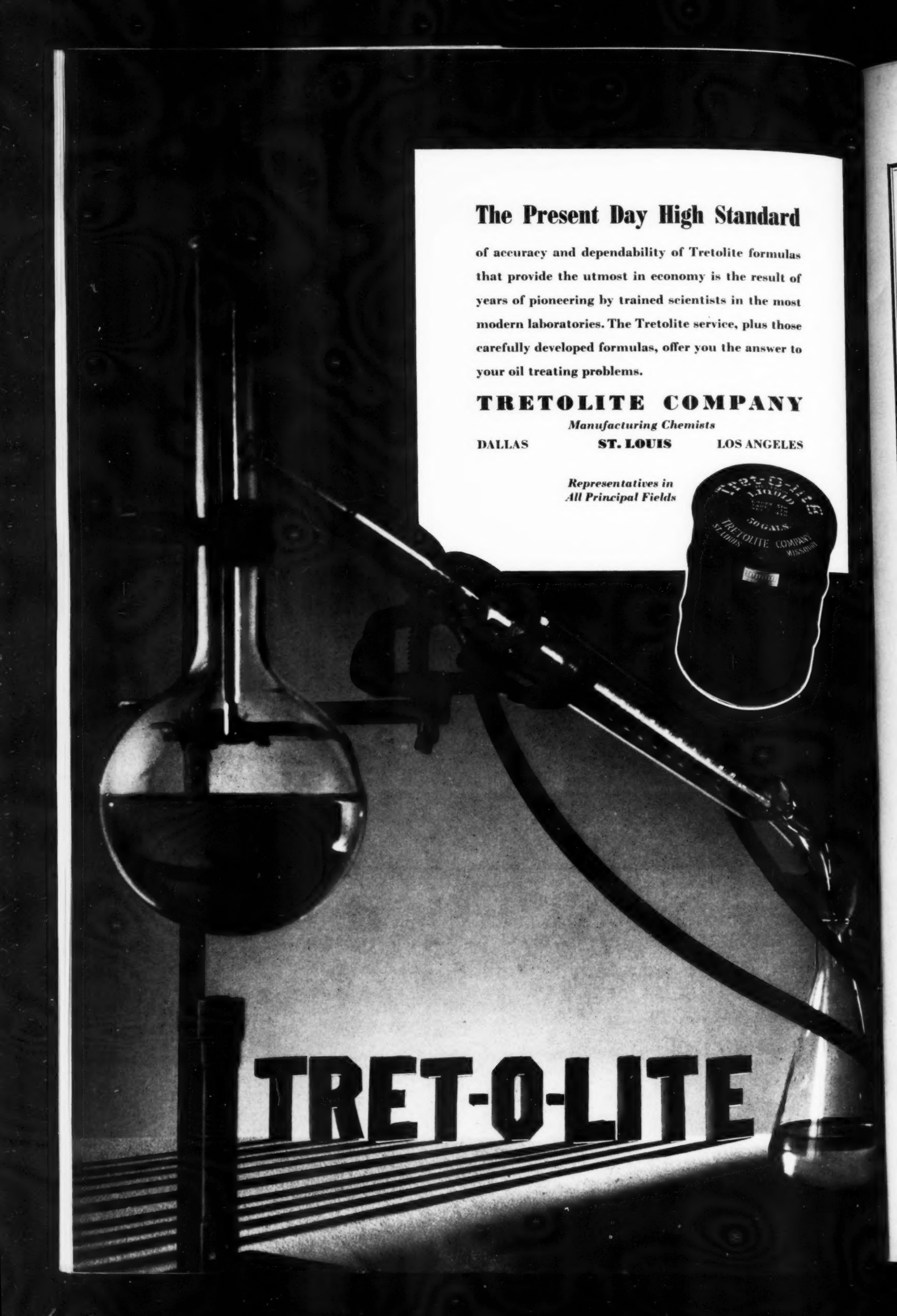

THE Petroleum Engineer

MIDYEAR 1938

VOLUME IX NUMBER 10

A MAGAZINE OF METHODS FOR OPERATING MEN

ANNUAL ENGINEERING REVIEW NUMBER
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•

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•

American Association of Petroleum Geologists, Mid-Year Meeting—September 27, 28, 29, 30, October 1, and 2, El Paso, Texas.

•

Society of Automotive Engineers, National Regional Fuels and Lubricants Meeting—October 6 and 7, Tulsa, Oklahoma.

•

American Institute of Mining and Metallurgical Engineers, Petroleum Division—October 6 and 7, San Antonio, Texas.

•

American Gas Association—October 10, 11, 12, 13, and 14, Atlantic City, New Jersey.

•

National Stripper Well Association, Annual Meeting—October 18, Tulsa, Oklahoma.

•

Oklahoma Stripper Well Association, Annual Meeting — October 18, Tulsa Oklahoma.

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Independent Petroleum Association of America—October 19, 20, and 21, Tulsa, Oklahoma.

•

Mid-Continent Oil and Gas Association, Texas Division—October 27, 28, and 29, San Antonio, Texas.

•

American Petroleum Institute, 19th Annual Meeting—November 14, 15, 16, 17, and 18, Stevens Hotel, Chicago, Illinois.

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American Society of Mechanical Engineers—December 4, 5, 6, 7, 8, and 9, Philadelphia, Pennsylvania.

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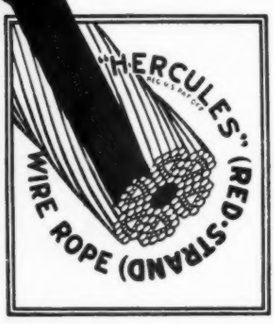

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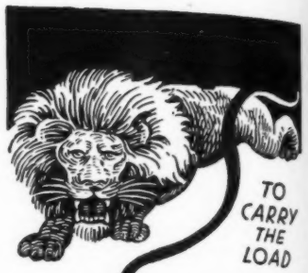

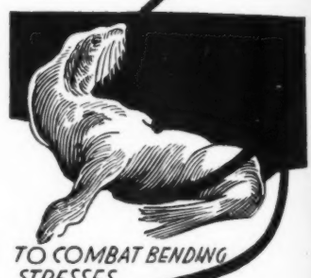

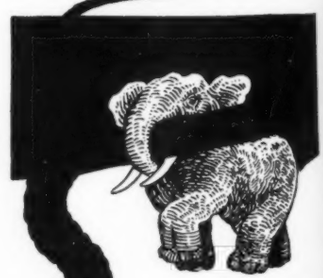

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Editorial

THIS issue of *The Petroleum Engineer*, the Midyear number, is devoted exclusively to an engineering review of progress and trends. The specific branches of the industry covered in the review include: geophysical prospecting, drilling, production, refining, natural gasoline manufacture, and pipe line transportation.

Geophysical exploration methods for petroleum were introduced in the United States less than 20 years ago, and almost overnight petroleum exploration was speeded up to a degree undreamed of. Since its introduction, geophysics has made tremendous advances and has played an important part in the discovery of new fields. Geophysical equipment and methods are constantly being improved. Not content with the progress already made, the geophysicist is evolving new methods of exploration that may uncover buried deep-seated structures of low or vanishing relief that at present are beyond his reach.

Within the last few months a well was drilled to a depth of almost three miles, or 2000 ft., deeper than any well has ever reached—a truly remarkable tribute to the men, materials, and equipment employed. It reflects the progress in drilling practice.

Increases in rotational speed are being experimented with on heavy rotary-drilling operations. Elsewhere a new turbo drill, recently developed, operates at 600 r.p.m., and at times as many as 1200 r.p.m. when using a small bit of 8-in. diameter.

Remarkable footage drilling records are being made. Cores have been taken by rock-bit from a depth of 50,000 feet. These things are being done today; they may be surpassed tomorrow.

Science and scientific devices are responsible for many improvements in production practice. Bottom-hole data are used not only in reservoir control but also in checking the individual well operation. Gravel-packing is being used to overcome sand problems in pumping wells. Deep wells mean high lifting cost when natural flow ceases, so energy is carefully conserved to prolong flowing life.

In the refining industry what do we find? A trend toward higher-octane gasoline. It is predicted that within three years 100-octane fuels will be in demand. Aviation fuel requirements, which are very exacting, are increasing rapidly. Obsolete units are being replaced by new type units to meet new processing needs. Total cracking plant capacity in the United States is the greatest in the history of the industry. Cracked gasoline output now exceeds that of straight-run gasoline.

In the refining of lubricating oils solvent extraction is constantly being improved. Plants are being simplified in design. Modern engines demand quality and stability in lubricating oils. The improvement of these properties in lubricating oils are constantly being sought by the technologist. It is predicted that if the trend toward solvent-treated oils continue the capacity of present plants will be insufficient. Research on the synthesis of lubricating oils is bringing about many improvements. Changes in refining methods are likely to increase rather than diminish. So rapid are the improvements in refining that the most modern plant installed today may be obsolete five years from now.

In the manufacture of natural gasoline there is a trend toward higher operating pressures and light high-speed engines and compressors. Fired heaters are coming back into use. Tube stills have been modernized and cracking of absorption oil, so common in old heaters, has been eliminated. Polymerization has increased the importance of recovery and utilization. Propane refrigeration is used to increase the extraction of butane. These improvements mean greater economy of operation.

Electrical methods of protecting pipe lines from corrosion were unheard of ten years ago. Today cathodic protection is in extensive use and many methods of cathodic protection are being devised. Many pipe line engineers are working on this problem; recently they formed an association in the Mid-Continent by means of which they can pool their experience and results and thus expedite solutions of their problems.

These are among the progressive trends reviewed in this issue.

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THE Petroleum Engineer

MIDYEAR, 1938

Progress in Natural Gasoline Manufacture

By J. W. VAIDEN, Manager, Natural Gasoline-Natural Gas Division
and
F. E. FISHER, Control Chemist, Natural Gasoline Division, Skelly Oil Company

CONSIDERING the natural gasoline industry as a whole, excellent progress has been witnessed during the last year both from a technical and economic standpoint. Economic conditions, gradually improving during the last several years, seemed to be on a decided upward trend at the beginning of the year 1937 and resulted in considerable new building and the modernization of existing properties. Capital expenditures of some manufacturers reached new highs and the profits for the year were, for the most part, encouraging.

Plans for a wide variety of new construction projects and the modernization and expansion of existing properties have been made by several gasoline manufacturers although most of the actual work is being held up pending a more favorable outlook. Inquiries now in the hands of various equipment manufacturers and contractors indicate a decided tendency of the industry to take advantage of recent developments in technology and engineering. Plants constructed during the last year, and future construction planned, show a considerable deviation from the "hit and miss" form of construction common throughout the industry not so many years ago. Plants are now built, not merely with an eye toward the use of proper engineering materials and equipment for the job at hand, but with considerable thought for the future in the selection of materials and equipment and in their arrangement in the plant from an operating standpoint. Present construction is characterized by the use of equipment designed for higher operating pressures, by light, high-speed engines and compressors requiring small foundations, and by motor- and turbine-driven pumps. Several plants are successfully using fire pre-heaters in their distillation equipment, thus virtually eliminating the usual boiler plant. Many plants now incorporate in their design a means of reconditioning absorption oil. Considerable interest is being shown in the conditioning of cooling water for scale and corrosion control, and in the proper treatment of boiler-feed water. New designs and modernization of old plants usually include overhead piping as a means of reducing corrosion and resultant leakage and minimizing the cost of repairs. Pipe lines are being used to a greater extent than ever before in the transportation of gasoline of all grades. Many new gasoline pipe lines are among the projects planned for this year.

Improvements in processing technique and the resulting new equipment necessitated have been outstanding features during the last several years, and the increased demand for more efficiently operated plants makes obsolescence an important factor. The days when a natural gasoline manufacturer might profitably operate antiquated

equipment have gone and recognition of the importance to the industry of obsolescence of processing equipment is increasing.

Proration and unitization have had a beneficial effect upon stabilization of natural gasoline manufacture. The construction of many small plants has been discouraged and the construction of large ones delayed, with the result that plants built today are larger and better constructed than was common in the past and are on a secure economic basis. This is largely because it is possible to determine with relative accuracy the size of the plant necessary to process the gas produced in a given area and to predict the supply of gas over an extended period.

Gasoline- and gas-treating have occupied the attention of research and development men to a considerable extent during the year. The cupric chloride process came into widespread recognition during the year and its continued use is evident. Important improvements have been made in the older processes and technologists are still striving to reduce the cost and increase the scope and effectiveness of the treating process.

The importance of recovery and utilization of the lighter fractions from natural gasoline is increasing. The increased use of the polymerization process is largely responsible for this condition, although the use of butanes for industrial and domestic fuel has increased rapidly in the last few years. Throughout the Southwest and on the West Coast the use of butanes as fuel for motor trucks and tractors has increased, as has also the use of the product as a refrigerant for trucks and cars transporting fruit and meats. The use of butanes as fuel for internal combustion engines on construction projects, irrigation, and well drilling has widened the market considerably. Throughout the Southwest the use of butanes as domestic fuel has shown great progress and is still increasing in volume. The use of tank trucks for transportation has been largely responsible for the increased application of butanes as fuel.

Maximum recovery of the lighter fractions in the gasoline plant necessitates a considerable departure from customary plant design. High-pressure absorption, or two-stage absorption, using a high-gravity, low-molecular-weight absorption oil is desirable, together with cooling of the absorption oil to comparatively low temperatures by means of propane or butane refrigeration. All equipment must be designed to handle the highly-volatile product of such a plant and fractionation equipment must be efficient. Purchasers of butanes for fuel and for industrial purposes are becoming much more critical of the quality of the product purchased, demanding a well-fractionated product, and showing a preference for iso-butane. This discourages, to a considerable extent, the previous practice of some manufacturers of selling "fractionator overhead" as butanes for fuel and makes necessary the operation of an efficient fractionation unit.

Popularity of the polymerization process has increased rapidly among refiners. At least two installations have been made that depend upon the light fractions from natural gasoline manufacture for their operation. The success from an operating and economic standpoint remains to be proved, and progress is being watched with great interest by the industry.

The various polymerization processes now available are still fairly new and it is only natural to expect that future developments will introduce improvements in engineering and design. Present designs of plants are costly, both from the standpoint of installation and operation. The units are large and as designed have excess capacity.

The value of the polymer product as a high anti-knock blending material and as a source of iso-octane for ultra-high octane number aviation and motor gasoline seems unquestioned. Octane numbers as high as 150 for aviation fuel have been predicted. Recent purchases of aviation engines by the U. S. Army Air Corps are based upon design convertible for use of 100-octane number fuel. Commercial air lines are awaiting a suitable reduction in the price of the high-octane fuel to change their purchasing specifications accordingly.

Natural gasoline manufacturers are in doubt as to how the manufacture of large volumes of polymer gasoline by refiners will affect the natural gasoline market. There has been much discussion of this question and as yet no one has arrived at a definite answer. Time and economics must decide. There is no doubt, however, but that increased conversion of refinery gases into polymer gasoline will have its effect upon the gasoline market as a whole, if for no other reason than the actual increase in production resulting therefrom. Stocks of motor fuels being large, despite reduction of refinery output, it would seem that the increase in motor fuel production by the polymerization plants now in operation and those to be built during the year might have some effect upon the price structure of natural gasoline. On the other hand, increased demand by the refiner for feed for his "poly" plants may result very favorably for those natural gasoline manufacturers situated in areas where the economical transportation of "poly" feed to the refinery is possible.

If and when development of the cracking and polymerization processes brings forth a comparatively inexpensive unit that can be operated efficiently and economically upon the comparatively small amount of feed supplied by the average gasoline plant the way will be paved for a greater utilization of the products of the natural gasoline plant and probably greater profits and stability of markets than is common today.

The natural gasoline industry has an excellent opportunity to participate in the trend of the petroleum industry toward the manufacture of a wide variety of chemicals by synthesis. Hundreds of types of chemicals have been prepared from natural gas in the laboratory and await only the perfection of processes or reduction in manufacturing costs to compete commercially with chemicals from other sources.

The research and development required before such processes become commercially practicable entail the expenditure of much time and money. The full utilization of such possibilities depends upon working out the economic and practical phases of the processes shown by research to have possibilities. The value of such work to the natural gasoline industry is growing and should receive careful thought by all concerned with the economic future of the industry.

In contemplation of what the future may have in store for the natural gasoline industry we must not lose sight of the demands of the present. Economic conditions within the industry, and in business in general, make careful attention to efficient operation of existing plants most desirable. There are few plants in which the efficiency of gasoline extraction, or the cost of manufacture, can not be improved upon by methodical application of analysis—physical, chemical, and mathematical. The days of haphazard operation are past, and present-day operation requires a much higher standard than ever before if profits are to be realized.

The executive, the technologist, and the operator should all work together, using every facility at their command to increase operating efficiency and develop and apply improvements in existing equipment and technique. The results, and the future of the industry, will depend upon how well the job is done.

Progressive Trends in Oilfield Development Practice

By K. C. SCLATER

AMONG the most significant trends observable in oilfield development practice is the rapid swing toward scientific methods of production in recent years. Oilfield development today calls for specialized methods and equipment. Accurate and tangible data regarding subsurface conditions can now be obtained while the well is being drilled; indeed, the procuring of these data is a part of modern routine drilling and development operations. It is no cause for wonder then that among progressive trends today, the increasing efforts that are being bent toward a solution of the well-spacing problem looms as one of the most important, particularly in regard to the influence it will have in establishing sound field development practices.

Well-Spacing

Well-spacing is a fundamental consideration in orderly and efficient oilfield development, a perplexing problem regarding which there has always been much general disagreement both within and without the industry. One difficulty is that tangible evidence of underground conditions in new fields is hard to obtain until several wells have been drilled, so a tentative program of development must therefore be followed until data on reservoir conditions are available and a permanent plan of development adopted. Another difficulty is the legal restrictions that may be imposed on an operator in complying with certain conditions written into the lease agreement. He may be required to follow a method of operation that is not compatible with sound practice and therefore detrimental to the proper development of the pool.

These two difficulties are probably at the root of most troubles encountered in connection with the well-spacing problem. Lack of an adequate well-spacing program has been found in many instances to result in the drilling of more wells than are actually necessary for economic ultimate recovery from a pool. The industry is now fully alive to the great economic loss, running into the millions of dollars yearly, that this item of excess wells entails and is making efforts to eliminate it. It is realized that the well-spacing problem is not one that can be solved by the individual operator or by a group of operators. The problem is bigger than that. It has fundamental engineering and legal aspects of far-reaching importance. All angles of the problem have been under investigation for two years by two committees, one composed of engineers and the other of lawyers. Recent reports of these two committees may lead to concerted action by the several oil-producing states in promulgating uniform regulations on well-spacing.

Should such concerted action be taken it would exert a beneficial influence on field practice and would remove the evils of too-close spacing. The evils that follow too-close spacing of wells are many. It is estimated that the present average yearly cost of operating wells in Kansas is 108 percent of the price obtained for the product.[1] This estimate is based on a crude price of $1.25 per barrel. Well-spacing regulations would afford the operator the fair chance of making a profit by reducing the drilling requirements. Too-close spacing has other disadvantages. It results in too many wells and a consequent reduction of the daily well allowable to a level so low that the revenue becomes insufficient to carry the investment. This has been the cause of recent economic distress among producers. Unless wells are properly spaced reservoir energy cannot be efficiently utilized. The net result is an increase in development and ultimate production costs.

Development Aids

Physical conditions in the reservoir of a new pool are becoming matters of intensive investigation during the time that development of the pool is in progress. Important aids called into play for this purpose include mechanical coring, core analysis, electrical logging, and temperature and pressure measurements. These aids are finding an ever-increasing application in routine development and drilling operations. A well drilled today, whether or not it is productive of oil or gas, is made to yield scientific data of intensely practical value.

The existence of connate water in oil sands in surprisingly large quantity has been revealed. Subsequent investigation has pointed to the practical significance of connate water in a reservoir; that is, how it affects permeability and oil reserves, and what effect its presence on removal will have on production and well drainage.[2]

In a pool that has a large gas-cap, the determination of the gas-oil contact in the reservoir will have an important bearing on the development of a field. Electrical logs of wells are used to make such a determination. If the gas-cap area is extensive it may be desirable to carry the oil string through the zone occupied by the gas to exclude the upper free gas, in order to take care of the natural lowering of the gas-oil contact, which might lead to a condition of insufficient submergence in the well and result in high gas/oil ratios.[3]

Drilling Time

Low well production allowables have emphasized the need for still greater economy in drilling and completing wells. Longer service life and lower upkeep costs are demanded of equipment. Efforts toward greater economy are in general evidence.

Field engineering studies of drilling operations are valuable aids in initiating drilling economies. One such study that has shown promise is concerned with an investigation of drilling time.[4] During development of a pool the time required to drill a unit depth in certain formations is observed and recorded. Porous zones and their thickness may be determined on rotary wells by such study. In West Texas, for example, it was observed that porous dolomitic limestones can be drilled faster than impervious dolomitic limestone.

The results of these time studies indicate that a close relationship exists between drilling time and well potential, at least in one pool in West Texas. The information also aids in determining casing points, total depths, method of acidization, the placing of nitro shots, and the like. Even after the well is completed the original record of drilling time can be used in well-repair work in determining the proper plug-back depth, selecting suitable packer seats, and in determining the proper position of liner and pipe perforations. In fields in which this method of time study is practicable and applicable the advantages of making drilling time data an integral part of the drilling record are obvious. It is valuable supplementary information on rotary wells. It eliminates guess work, fosters closer

drilling supervision, and provides for greater use of recording devices on rotary rigs. It may also be used as a yardstick in determining drilling efficiency.

Drilling Operations

For the actual drilling of a deep well, close study of rotating speeds, weights on the bit, types of bit, and drilling fluid is necessary. These are the controlling factors in any drilling operation, and of equal or greater importance is the necessity of requiring that the operating personnel adhere to the use of these factors and those values that have been determined as most suitable to the job in hand.[5]

Drill pipe and bit are treated with consideration in deep wells. It is customary and sound practice to keep the drill pipe in tension while drilling. This is done by concentrating the weight on the bit at the drill stem. It insures a straight hole and increases the life of the drill pipe. Proper balance between weight on the bit and rotating speed is closely controlled by the use of indicating and recording instruments on the derrick floor. Constant studies of rotating speed and bit weight are being made in the field to determine proper applications for the various conditions encountered.

Welding Casing

There is a gradual trend toward the practice of circumferential field welding of casing. Joint efficiencies obtained in the welding of casing have been studied. According to reported test results slip- or sleeve-type joints showed relatively low efficiency. Bell-and-spigot, straight-butt, and double-bell and chill-ring joints gave efficiencies of 80 to 100 percent. Proper choice of joint and welding technique may give efficiences of 90 to 100 percent.[6] Time analyses indicate that bell-and-spigot joints may be run more rapidly than butt joints. The estimated saving by using welded casing is 10 to 15 percent. The longest string of welded casing used to date in a well was set recently by the Carter Oil Company in a well in Oklahoma. It was 8100 ft. long and consisted of 7-in. O.D., 26-lb. range 3, special casing. All joints were electrically welded. Two types of welded joints were used, U-bevel and V-bevel, on plain end pipe. After the casing was set it was subjected to a pressure of 1200 lb., and it held this pressure for 54 minutes without showing any pressure drop.

Sub-Pressure Drilling

Completion of wells under controlled sub-pressure (a pressure less than the pressure of the formation being drilled) is always desirable. If the pressure exerted by the drilling fluid exceeds the formation pressure it may result in clogging the face of the sand. On the other hand, should a high-pressure sand be penetrated a blow-out may occur if sufficient pressure is not exerted by the drilling fluid. This method of completion is successful and is justified when the sub-surface conditions make sub-pressure drilling-in essential. The use of oil or oil and gas as drilling fluid is of no significance in itself, but the primary reason is to reduce the pressure on the drilling interval to a point below the formation pressure. Although this work in the Dominguez field, California, is in its experimental stage it appears that the maximum benefits to be derived are in wells that have a highly permeable sand and from zones that have been somewhat depleted. Additional completions may provide improvements in sub-pressure drilling practice that will make this method more successful than it would seem to be at present.[7]

Marine Drilling

Drilling in the open waters of the Gulf of Mexico off the Coast of Louisiana and Texas is bound to exert a profound influence in marine drilling operations.

Suitable structures for these operations are the subject of intensive study by petroleum engineers. Structures for drilling in open water must be made safe to withstand winds of hurricane force. The cost of these structures may run as high as the cost of drilling. Wood piling so far has been the principal type of structure in use. Sheet steel piling and other designs are nevertheless having the attention of engineers. There is the possibility of using floating equipment, but where the water is deep the use of this type of equipment may be precluded.[8, 9]

Power for the operation of rigs on water locations is an important consideration and opens a wide field of experimentation. On one modern rig, the steam plant employs all the latest devices for economizing in fuel, steam, and water. As oil and water have to be barged-in, the necessity for economy is imperative. Six features that make for the utmost economy under the conditions are: an automatic control, dutch ovens under the boilers and superheater, fully insulated boilers and steam lines, the use of superheated steam, reciprocating engines operated with cut-off control, and a condenser that reduces the back pressure on the engines and returns clean hot water to the boilers.[10]

Portability

A definite and persistent trend in regard to drilling equipment is the demand for portability. Deep drilling equipment is now unitized and its weight and compactness are given consideration in design.

Even in the drilling of shallow wells the utmost in portability is demanded. The object is to lower drilling costs by reducing the time lost in moving and rigging-up. One notable effort in this direction is the recent introduction of a portable collapsible steel derrick. It is 84 ft. in height and collapses into three sections of equal length (28 ft.). The upper part is in two pieces, the middle portion in four pieces, and the bottom portion, which swings into the stationary portion, is in two pieces. On the first location at which this derrick was used, the derrick was erected complete in place in three and one-half hours by the drilling crew and truck drivers. Only about 70 bolts are used in its erection and dismantling.

Depth Records

Once or oftener each year since 1929, excepting 1936 and 1937, the deep-drilling record has been broken and a new one established. During the last eight years, from midyear 1930 to midyear 1938, the maximum drilling depth reached has increased from approximately 8400 to 15,000 ft., an average of some 825 ft. a year. The present deep-drilling record of 15,004 ft. exceeds the previous depth record by more than 2000 ft. and is the greatest depth-interval yet attained between any two consecutive records.

The mere matter of breaking records, however, is of no importance; what is significant is that the maximum depth being reached by the drill is increasing at a rate the accelerating pace of which is typical of the progress being made in oilfield development and drilling practice in general.

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Recent Trends and Progress in Production Practice

By RALPH H. KING

THE predominant trend of the production phase of the petroleum industry has been the tendency of the operators to extend the use of scientific methods. This tendency has been noticeable not only in the methods of preparing the wells for production and of lifting and treating the fluid, but also in the auxiliary processes and in the abstract aspects of operation.

Gravel-Packing

Gravel-packing has been used more extensively in the completion of new wells and in the re-working of old wells. This process was developed some years ago as a means of increasing the flow of water wells but has recently been adapted for use in improving the production of oil wells. The "developed" gravel-pack used in water wells is formed by surging water through the gravel to sort the grains, the finer gravel being moved outward against the sand face and the coarser gravel being drawn against the screen or perforated pipe. Although this method of "developing" a gravel-pack is not adaptable to use in oil wells, a somewhat similar result has been obtained by introducing a batch of fine gravel followed by a batch of coarse gravel. The fine gravel prevents the entry of sand into the well but its permeability is less than that of the coarse gravel. The use of coarse gravel adjacent to the screen or perforated pipe where the velocity of flow is greatest reduces the frictional resistance to flow. The method is not so effective as that used in water wells, because the gravel tends to become sorted in horizontal layers rather than in concentric cylinders and the effects are thereby restricted to that portion of the flow that is upward, which is admittedly a relatively small part of the total flow outside the screen.

It seems logical that oil may be used to "develop" a gravel-pack in oil wells similar to the gravel-pack developed in water wells by surging water through the gravel. The gravel-pack is even more beneficial to oil wells than to water wells because of the greater viscosity of oil and its consequently greater tendency to carry sand and silt particles in suspension.

To gravel-pack an old well it is necessary to underream through the productive sand in order to provide the space for the gravel. This under-reaming leaves exposed a clean sand face, which in itself is desirable.

Determination of Optimum Operating Conditions

Scientific instruments are being used more extensively to determine the characteristics of operation of oil wells and to indicate the optimum pumping speed, length of stroke, size and position of working barrel, and other controllable conditions.

Data particularly applicable to individual wells are obtained by devices such as the dynamometer and dynagraph. These and other instruments are used to determine characteristics of operation of the pump and pumping equipment. Although these are not new instruments, they are being steadily improved and their use is being constantly extended to other wells and fields.

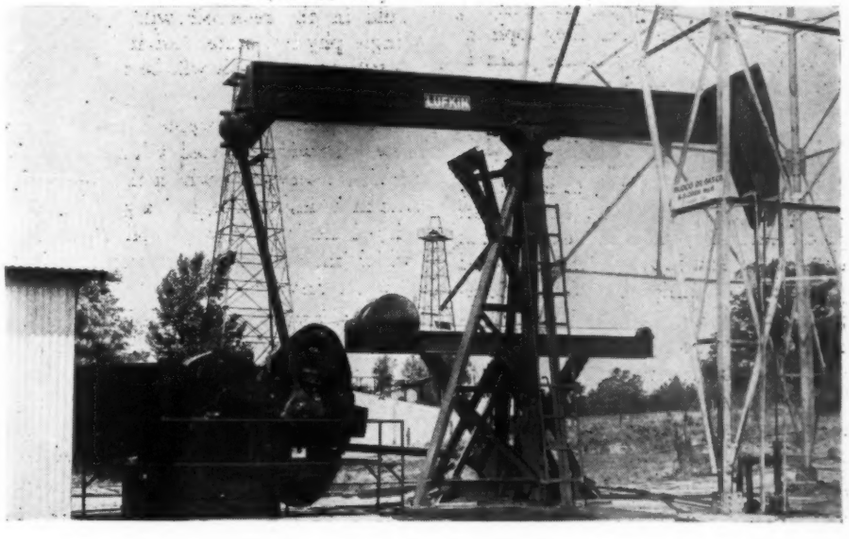
By the use of measuring instruments such as the dynamometer it is possible to determine whether the working barrel is properly placed, whether the pump is large enough to lift all the fluid that the well can produce, whether the pump is gas-locking, whether the pumping unit is properly counterbalanced, and whether the pump is being operated at the optimum speed and length of stroke. Records of periodic measurements of an individual well may also show changes that will indicate lowering of fluid level caused by leakage or other well conditions, and will indicate profitable remedial measures.

Cementing

Application of cementing technique developed in the last few months has resulted in the exclusion of water from wells that would otherwise have been abandoned. The introduction of cement under high pressure, known as "squeeze cementing," has been used effectively in many fields. Commonly a cement retainer is used on the bottom of the tubing, as this procedure relieves the casing of the strain imposed by high pressure.

Some wells in the East Texas field and other areas do not offer sufficient resistance to flow to permit establishment of a high pressure. For such wells the stage cementing method has been developed. The cement is introduced in two, three, or more batches, each batch being allowed to set sufficiently before the introduction of the next so that it will not be displaced. As successively smaller pores are thus filled the resistance to flow is increased and the last batch is introduced at the desired pressure.

Several of the companies manufac-



Three-well pumping unit in East Texas field

turing cement have added collodial material to the cement. When such cement is allowed to set for a few minutes the colloidal material forms a stiff gel, preventing displacement of the cement before it has set and offering substantial resistance to flow. For several years the manufacturers of cement have been adding the gel-forming material to ordinary Portland cement, but within the last few months they have added it to the special slow-setting cements also.

Core Analysis

Core analyses have been used extensively for many years to provide data for determining the proper well-spacing pattern and input pressure for water-flooding operations. Core analyses are now being used in conjunction with bottom-hole measurements as a guide in selecting optimum conditions for "primary" recovery. Wrapping and packing cores and shipping them to the laboratory caused an objectionable delay and, if the cores were not properly wrapped, the condition of the core when analyzed might be entirely different from that when cut, and the results of the analysis misleading. To obviate this unreliability field laboratories have been built in trucks that can be driven to the well site so that the cores can be analyzed as they are taken from the well.

Progress in Management

The coöperation of the operators in the K. M. A. field is an example of the advancement in the less tangible aspects of petroleum production. From the time of the discovery of deep production the producers have restricted the drilling of new wells and have abided by proration schedules to the mutual advantage of the independent, the major company, and the land owner.

Reservoir pressure in the K. M. A. deep zone is erratic and is declining rapidly. The Deep Oil Development Company operates a gasoline plant in the field, taking gas from the company's own wells, and the residue gas is being used to maintain the reservoir pressure on the company's leases. This practice is commendable, as inevitably the owners of adjacent leases must profit indirectly to some extent, but even more laudable is the proposed plan of the Phillips Petroleum Company, Sunray Oil Company, and Continental Oil Company. These companies are constructing gasoline plants in the field and propose to furnish residue gas to any operator at nominal cost for use in maintaining reservoir pressure. The plan is not altogether altruistic, as the quantity of residue gas that will be available will far exceed the demands for fuel gas, and its sale at a low price is preferable to its wastage. Furthermore, the use of the residue gas for pressure maintenance operations will also serve to maintain a supply of rich wet gas for processing in the plants, as much of the gas will be repeatedly recycled. Nevertheless, the provision of a supply of gas for pressure maintenance at a cost far below the cost of compression will benefit the operator taking advantage of the offer as much as it will the gasoline plant operators.

Despite the fact that the East Texas field produces through the agency of a water drive, which apparently is lacking in the K. M. A. field, the plan would seem to be equally applicable to the East Texas field. Such a plan was, in fact, considered in the early life of the field, but was abandoned. It is not inconceivable that had the plan been put in operation the East Texas field would not now be producing an excessive quantity of water that presages a tremendous waste of oil that will be unrecoverable as well as a financial burden of disposing of the water produced.

Reservoir Study

Increasing attention has been given to reservoir study, both before and after development. The greater average depth of fields now being developed enhances the importance of proper well-spacing, completion, and production methods. Bottom-hole pressure increases with the depth of the well, and the trend toward greater depth has raised the question of physical state of the fluid in deep reservoirs.

It is a generally accepted fact that an increase in pressure increases the mutual solubility of the hydro-carbons that constitute petroleum and natural gas. It has been postulated that at a depth of 18,000 or 20,000 ft. the fluid in the reservoir will exist in a single physical state, and it is further postulated that this will be the gaseous state.

It is generally accepted also that a few wells widely spaced will adequately drain a reservoir in which the fluid exists in a single state, i.e., a gas field or an oil field of low gas/oil ratio in which movement of fluid is caused by a water drive.

These two facts have led some operators to propose the development of very deep fields as single-state, or single-phase, reservoirs. If the fluid were in the liquid state, this plan would be feasible and practicable, but there is some doubt as to whether or not the fluid might be in the gaseous state. Should it be, the plan would be satisfactory until the reservoir pressure had declined to the point at which the liquid began to come out of solution, whereupon the reservoir would assume the characteristics of the ordinary two-phase field, and more wells would be required. Flush production from these later wells would be comparatively small and the total return might be less in proportion to the cost than it would be were the wells more closely spaced from the first. Fortunately, equipment is available for taking bottom-hole samples that will indicate the physical state of the reservoir fluid. It should be borne in mind that regardless of the physical state of the fluid in the reservoir the fluid that is produced will be oil and gas as we know them after the pressure has been released.

Bottom-hole temperature and pressure measurements and bottom-hole samples are being used extensively to indicate conditions in the reservoir. Formation gas/oil ratio and viscosity and surface tension of the reservoir fluid affect the rate of flow through the reservoir and consequently the ultimate recovery obtainable at different rates of production. The data obtained by these methods are applicable more or less generally to all wells in a field.

From a study of the characteristics of the well fluid and the pressure it is possible to determine the optimum rate of production and the most advantageous method of separation of the gas from the oil. Demand for the products will determine the advisability of producing lean oil and rich gas or rich oil and lean gas. If it seems desirable to retain all the light hydrocarbons possible in the oil, stage separation can be utilized, and analysis of the fluid will indicate the proper pressure to maintain on each separator to release the minimum amount of light hydrocarbons as gas.

When pressure is reduced in steps or stages a smaller quantity of the light hydrocarbons is entrained in the gas. If the wet gas is being processed in a gasoline plant and it is desirable to produce a rich wet gas, separation of the gas in single stage results in the entrainment of much of the light hydrocarbons as vapors partially condensed in the gaseous phase.

The equilibrium constants, commonly known as K-values, have been used extensively by at least one major company in determining optimum rate of production and method of separation of oil and gas.

Advancements In Acidizing Wells

By W. W. LOVE

DURING the last 12 months, when overproduction and high potentials were prevalent everywhere, acidizing had its greatest year since the invention of the art in 1932. Acidizing has come into use not only to increase a well's production, but also for the conservation of reservoir energy and the development of reserves. Another object is the correction of high gas/oil and high water/oil ratios.

Several new and important improvements have been recorded during the year both in products and in methods and technique of application. Sometimes the advancement has been made at the expense of past practice and theory, but in each case the benefits resulting from the change justified the discarding of the older methods.

Organic Gel Plugs

One of the most important advancements has been the increase in the applications of organic gels. This accessory chemical was designed more than two years ago for use as a temporary bottom-hole plug during the acidizing of a well. It had been known that acid always followed the path of least resistance and in some wells this path led into lower sands or depleted "thief" sections that would not respond to the acid. Sometimes these lower zones carried water and it was desirable to keep the acid where it could react only with the oil-bearing sections of the producing formation.

The organic material, mixed with a certain type of bacteria, is pumped into the well ahead of the acid as a liquid or colloidal suspension. Within a half hour it gels and will plug effectively the pores in the formation. The well is then acidized while the bottom of the hole is protected by the jelly seal plug. Within 24 to 48 hours, depending upon the bottom-hole temperature, the bacteria consume the jelly substance, causing it to become liquid again so that it can be easily bailed, swabbed, or pumped from the well.

Jelly seal lends itself to many uses because of the ease with which its specific gravity can be varied. Its specific gravity can be made slightly greater than that of water or can be increased until it exceeds that of the densest brines. It can be made to float on salt water or acid or it can be made to displace or support either. For example, one of the new uses of floating jelly seal is depicted in Fig. 1. This represents a tight or relatively impermeable, saturated limestone below a porous sandstone, both being exposed in the hole. Obviously, if the well were acidized in that condition, the acid would enter the sandstone and not only would no benefit accrue from the treatment but considerable damage might result from the solution of the lime cementing material and consequent loosening of the sand grains.

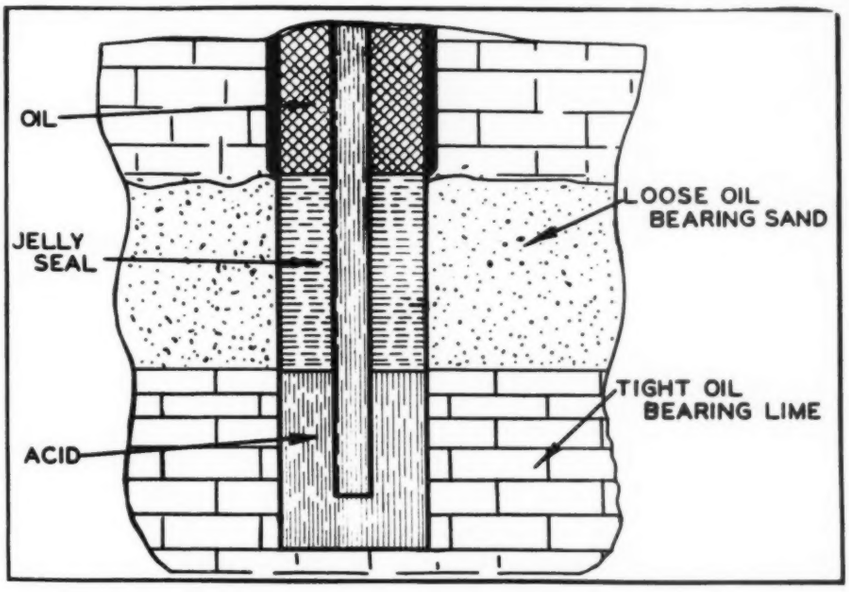


Fig. 1. Floating jelly seal

In order to avoid such difficulties, an organic gel, its specific gravity adjusted so that it will float on acid, is pumped into the well ahead of the acid in an amount calculated to fill the hole opposite the sand section. The height to which the jelly seal rises in the hole may be controlled either by a column of fluid in the casing or by a packer set immediately above the top of the sand.

When the acid reaches the bottom of the tubing, it stays on the bottom as the organic plug floats on it and rises in the hole until the upper sand is plugged-off. Now, only the tight lower limestone is exposed to the acid in the hole and whatever pressure is

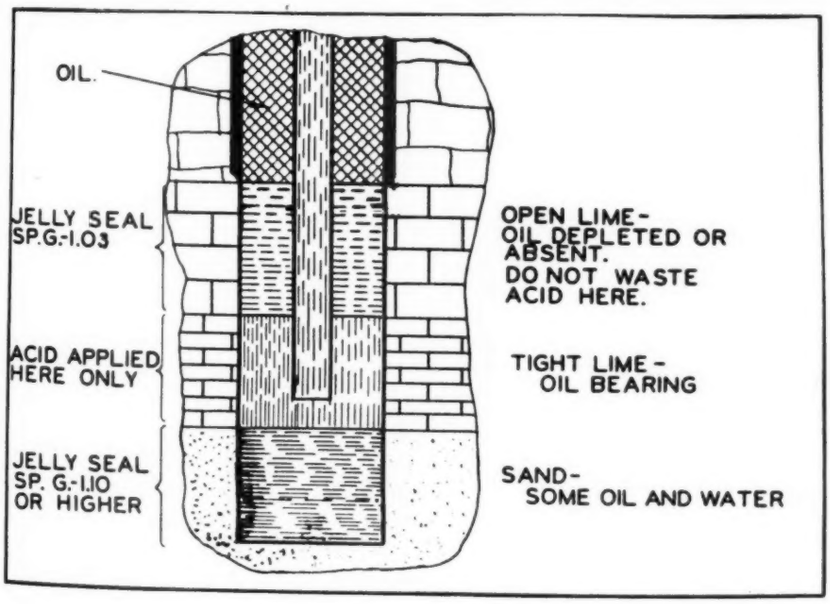

OIL
JELLY SEAL SP.G.-1.03
ACID APPLIED HERE ONLY
JELLY SEAL SP. G.-1.10 OR HIGHER
OPEN LIME-OIL DEPLETED OR ABSENT. DO NOT WASTE ACID HERE.
TIGHT LIME-OIL BEARING
SAND-SOME OIL AND WATER

Fig. 2. Parted jelly seal column

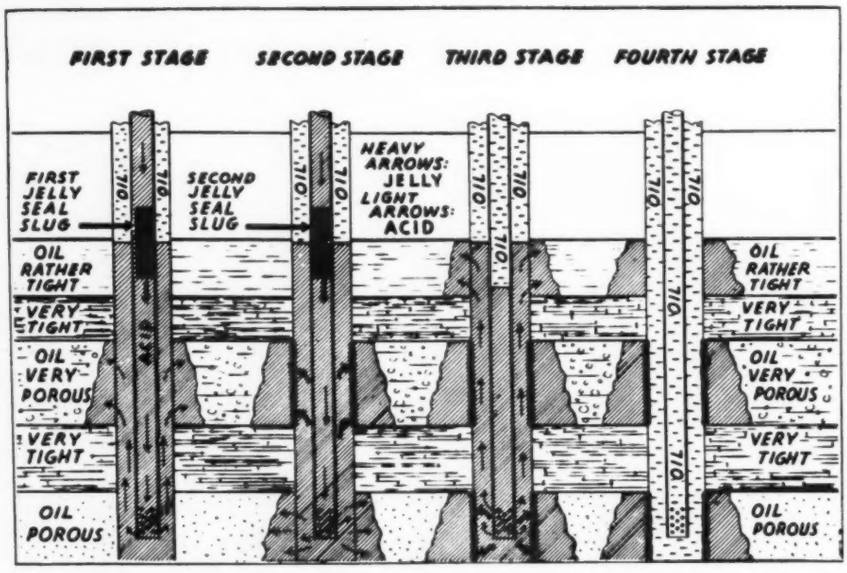


Fig. 3. Gel slug method

necessary to force the acid into the limestone can be applied without danger that the acid will go elsewhere.

A heavy organic gel is used chiefly to plug-off the bottom part of a well that produces a brine of high specific gravity from the lower part of the section. Ordinarily, acid will enter the water-producing pores as easily as, or more easily than, it will enter the oil pores and if precaution is not taken, an adverse water/oil ratio is likely to result.

Fig. 2 represents another new treatment, the parted column treatment, which has been particularly beneficial in western Kansas and in parts of the Permian Basin. By using a combination of light and heavy gel, it is possible to acidize a particular part of a formation and at the same time exclude acid from parts below and above the one being treated.

Here the lower sand is covered with a heavy plug having a specific gravity greater than that of acid or water, and the upper zone is plugged-off with a gel lighter than acid but heavier than oil. The acid is confined between the lower, heavy layer and the upper, floating layer.

The development of the gel slug method of treatment, Fig. 3, has made it possible to retreat wells economically in many areas where response to retreatment had previously been insignificant. Better response to initial treatment has also been obtained in some areas where it was known from past experience that conditions were suitable for such application. In the slug method, use is made of the fact that in many producing formations having comparatively large porosity and high permeability, the pore spaces vary greatly in size. The large pores drain quickly and the remaining oil is retained in the small pores. Somewhat the same condition exists after a well has once been treated. When acid enters this type of formation, it follows, of course, the path of least resistance, which is the large pores already drained. The problem is to divert it into the smaller, undrained channels.

Diversion is accomplished by interspersing comparatively small slugs of jelly seal between larger slugs of acid as shown in Fig. 3. The most efficient volume of each slug can be determined only by experience in any particular field, but it will be governed, in general, largely by the size of the pores. For example, in comparatively tight limestones, where only a small amount of acid is being used, 10 to 15 gal. of gel may be introduced after each 250 gal. of acid; in more porous formations, in which large quantities of acid are being used, slugs of as much as 100 gal. of gel may be used after each 1000 gal. of acid. As the acid enters the large pores, the gel is carried along in the stream and plugs these pores, preventing further passage of fluid. The acid will be forced to seek other channels, which likewise will be blocked when the next slug of jelly seal comes along. This method of treatment insures a more even distribution of the acid than could otherwise be obtained.

In the drilling of wells by the rotary method, organic gels have also found an application. Very recently, in a well being drilled in southwest Texas, circulation was lost when the bit penetrated the producing formation. Large quantities of mud and fibrous materials were pumped into the formation in an unsuccessful attempt to regain circulation. Fifty gal. of gel were spotted opposite the porous section and allowed to solidify for one-half hour. When the mud pump was started again, circulation was established within 20 minutes. The jelly seal was allowed to remain in the hole while the oil string of casing was being cemented and proof that it successfully withstood the weight of the cement is the fact that no fluid was lost during the operation. In another well in the same area, in which 80 gal. of gel was used, circulation was regained in 15 minutes. Fig. 4 illustrates the effect of gel when used in this connection.

Stage Treatments

In many areas where oil is produced from dense dolomite or siliceous limestone, it has frequently been found very difficult to acidize using conventional methods. The pores are so small and discontinuous that acid enters

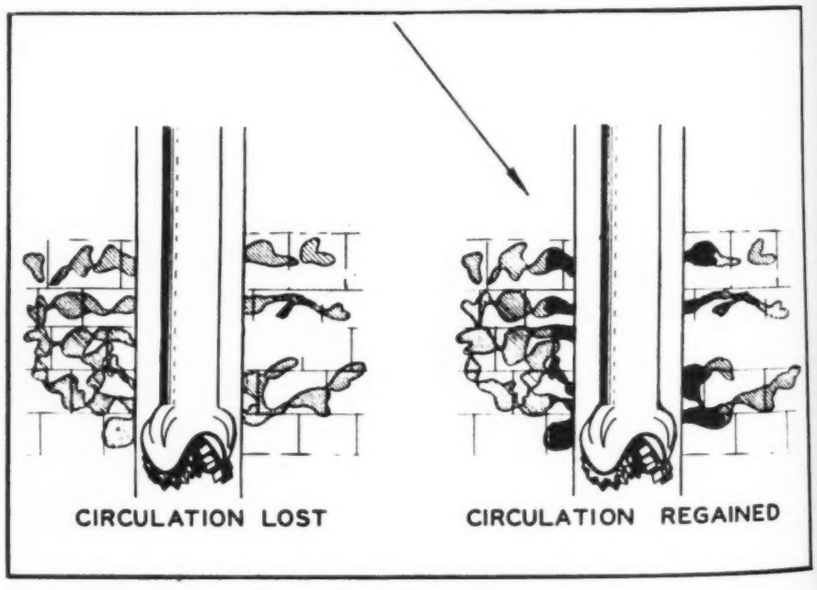


Fig. 4. Jelly seal to regain circulation

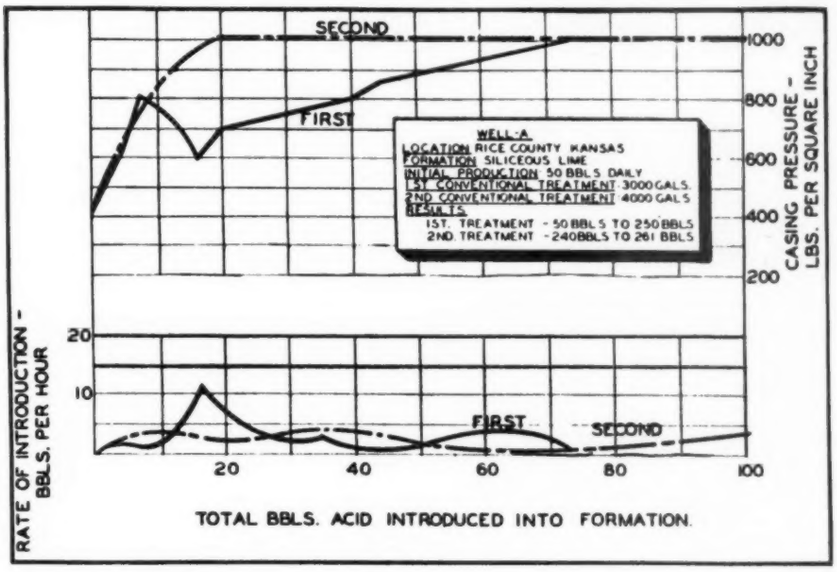


Fig. 5. Conventional treatment

them very slowly even under pressures as great as 3500 lb. per sq. inch. As a result of such slow percolation, the acid that first enters the formation is completely spent long before the treatment is completed. This means that the dead or spent acid is continually being pushed farther and farther into the formation. As spent acid is considerably more viscous than fresh acid and therefore more difficult to move, it is not uncommon to find that the pressure necessary to force acid into the formation becomes higher and higher as the treatment progresses. Such treatments are unsatisfactory from the standpoint of both the operator and the chemical service company. They consume many hours of time and the increase in production resulting is usually disappointing.

Within the last year, a method of acidizing such tight formations has been devised that results in satisfactory increase in production and eliminates much of the loss of time and the danger that is always present when high pressures are used. This method, known as the compound or stage method, consists essentially of a number of separate treatments made in quick succession using increasingly larger quantities of acid, the spent acid being removed from the well after each successive stage. The number of stages or the volume of acid to be used in each stage cannot be exactly determined until the actual treatment of the well is under way.

The first stage of the treatment is usually continued until a definite rise in pressure is encountered, which means either that the first acid that entered the formation is spent or that the insoluble materials of the formation that have been set free by the action of the acid are clogging the pores. At this point, the treatment is discontinued and the spent acid is removed immediately from the well.

The second stage of the treatment, which is begun as soon as the well is free from the spent acid from the first stage, proceeds exactly as did the first and is continued until either the pressure begins to rise again or all the acid to be used in the treatment is in the well. If the pressure begins to rise before the treatment is completed, it may be necessary to use a third stage, or, in rare cases, even a fourth. Figs. 5 and 6 show a comparison of two wells, one acidized by a conventional single treatment, the other by the compound treatment method.

Fig. 5 shows that in a conventional 3000-gal. treatment, the feeding rate was 11 bbl. per hour at 600-lb. casing pressure when 16 bbl. of acid were in the formation, but as the treatment continued, an increase of casing pressure to 1000 lb. could not prevent a decrease in feeding rate to less than five bbl. per hour. This definitely shows decreasing permeability. A second treatment of 4000 gal. produced no results because the effects of the first treatment were found to be lasting and the insoluble residues plugging the pores could not be dislodged.

Fig. 6 shows the results of the new stage treatment. A total of a little more than 2000 gal., as against 7000, increased the potential to 987 bbl. instead of 261. Fig. 6 shows that a maximum feeding rate of 35 bbl. per hour at a casing pressure of 100 lb. was obtained. Compare this with the feeding rate in the conventional treatment.

The effect of increasing permeability can be illustrated by data taken from the three-stage treatment of a Texas Panhandle gas well at which a compressor truck was employed. Fig. 7 shows the decreasing casing pressures and increasing feeding rate normal to this type of treatment. Here, an increasingly larger quantity was put into the well in each of the three stages, but in each stage the pressure was less than in the preceding stage and the time consumed was also less, both factors indicating increased permeability.

A variation of the compound treatment has recently produced good results in gas wells in the Texas Panhandle. It had been noted for some time that after being acidized, some gas wells would produce at a greatly increased rate for a number of hours and would then suddenly show a sharp decline. The decrease in production was thought to be caused by a partial plugging of the pores by insoluble residues carried from the formation by

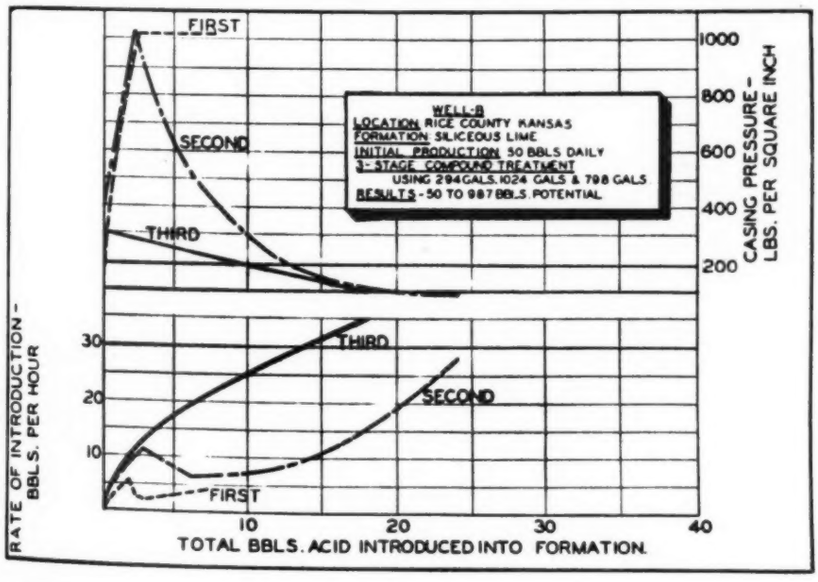


Fig. 6. Compound treatment

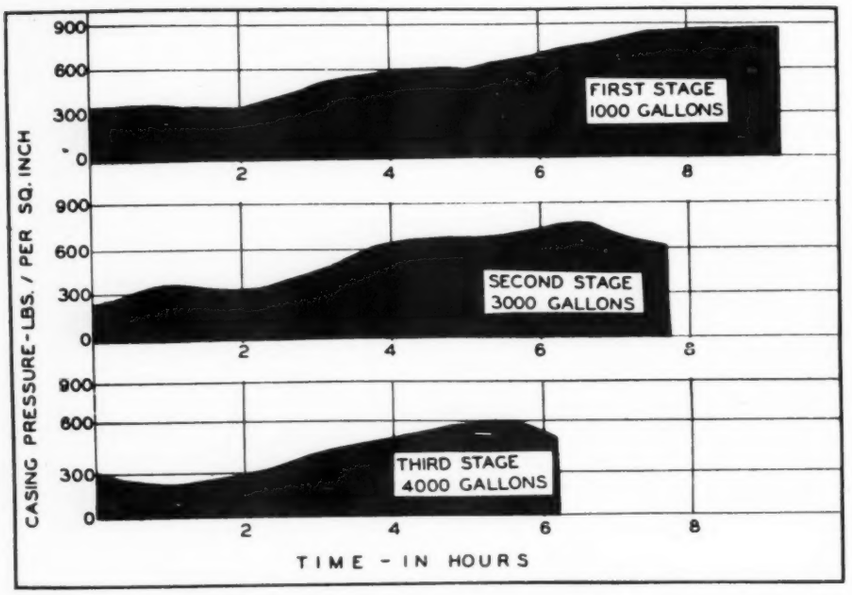


Fig. 7. Compound treatment.

the spent acid. It was believed further that the plugging was taking place near the bore of the well, where the pressure drop is a maximum. If so, then a small amount of acid forced into the formation only a short distance would relieve the blocking and permit the well to produce at its maximum capacity.

As an example of the results obtained by such a treatment, a well in Hutchinson County, Texas, may be cited. The well was producing 6,000,000 cu. ft. of gas per day before treatment. It was treated with a two-stage treatment of 1000 gal. and 3000 gal., after which it produced at the rate of 11,750,000 cu. ft. per day. After several hours, the production began to decline somewhat and it was decided to treat the well again using 1000 gal. of acid. The treatment was discontinued as soon as all the acid was forced into the formation. When placed on production again after the spent acid was blown from the hole, the well produced at the rate of 15,600,000 cu. ft. per day.

Although compound treatments have proved to be a boon in many fields, they have been somewhat of a boomerang in a few areas. It has been established that in fields producing from easily soluble limestones having high porosity and permeability, the response to compound treatments is not so great as the response to single treatments using the same volume of acid.

Sustained-Action Acid

Within the last few months a sustained action acid has been developed. This is an inhibited hydrochloric acid solution to which has been added an auxiliary chemical capable of retarding the rate of reaction with limestone and dolomitic limestone.

This new acid is particularly adaptable for use in formations that react rapidly and for retreatments. It has also been used to advantage in stage treatments, after the permeability immediately around the well bore has been increased by one or two stages of ordinary acid.

It has been found, in many conventional acid treatments, that the permeability right around the bore hole has been increased so much that a critical area or area of highest resistance is created back away from the well, that is, the formation has been overtreated near the well and undertreated farther away.

Efforts to eliminate overtreating near the bore hole by utilizing the services of two, three, or even more pump trucks have been unsuccessful. It was thought that faster injection of the acid would insure better penetration into the formation. It was found, however, that the reaction rate of the acid increased with its velocity through the formation and little was accomplished.

It has been found that wells treated with sustained-action acid not only respond as satisfactorily on initial treatment as offset wells but their rates of production decline were outstandingly decreased. Fig. 8 incorporates production figures on two Illinois wells of the same age to illustrate the effectiveness of sustained-action acid. This illustration is interesting inasmuch as the well treated with the new acid was decidedly the poorer of the two as shown by the pre-treatment production record. The well treated with ordinary inhibited acid declined rapidly in the first three months following treatment to about 50 bbl. per day and in five months had declined to 20 bbl. per day. The sustained effect of the acid used in the other well became apparent within ten days as the production did not decline but instead increased for a period of one month, after which its rate of decline was much slower than that of the offset well. Five months after treatment this well was producing 65 bbl. per day. During the five months a total of 18,375 bbl. of extra oil was produced from the well in which sustained-action acid was used.

Similar response has been obtained in wells in Texas, Louisiana, Illinois, Oklahoma, Kansas, and Michigan.

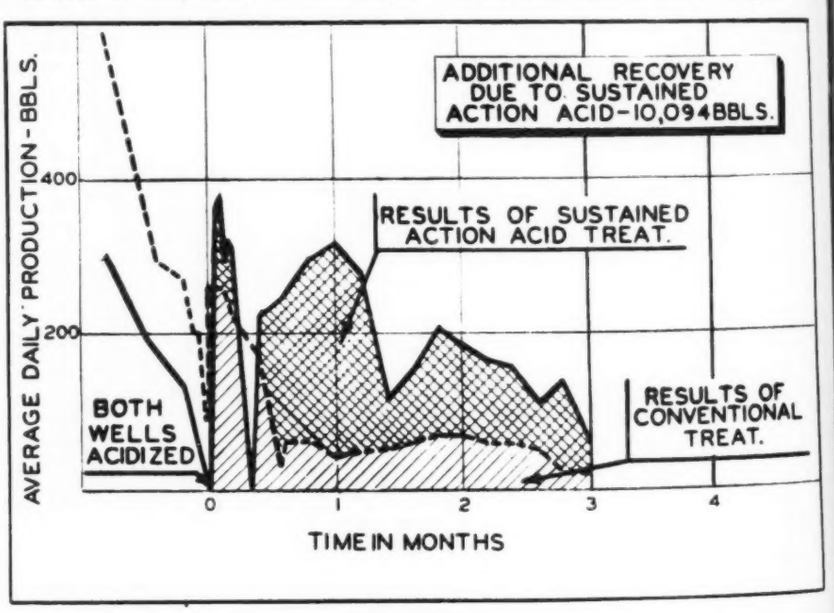


Fig. 8. Sustained-action acid

An earth drill, mounted on a truck, used in installing ground beds for cathodic protection of pipe lines

By

FRANK H. LOVE

Advancements in Pipe Line Construction and Operation

ADVANCEMENTS in construction methods, portable field pumping units, and cathodic protection procedure are among the recent developments in the pipe line industry, and progress in these fields has been attended by the manufacture of new equipment and improvement of that already in use.

Pipe line officials in recent years have devoted more attention to the care of their company's property than during the early days of the industry. Every effort is now made to maintain systems in service uninterruptedly and at a minimum cost for upkeep. For these reasons each year increased attention is given to cathodic protection. Virtually all major companies have staffs of corrosion experts who give their entire time to this matter. Many companies run electrical surveys on old lines to detect possible "hot spots" and dangerous areas before leaks appear rather than following the former method of allowing the leaks to point out the "hot spots".

Soil tests for determining corrosive areas are also made quite extensively before new lines are laid. The knowledge thus derived makes it possible to coat only those sections of pipe laid in corrosive areas. The former method of either leaving the line uncoated and unwrapped or applying coatings and wrappings over its entire length regardless provided inadequate protection in the one instance and often involved an unnecessary expenditure in the other.

Still another system of locating incipient leaks, so that they may be repaired before line losses become serious, is that adopted by some companies of building up the pressure in lines to considerably more than the operating pressure whenever an opportunity presents. Several instances are known in which line losses thus have been reduced 50 percent.

Cathodic Protection

The principle of cathodic protection is well known. Since the introduction of this method of protecting pipe lines about a decade ago constant effort has been made to improve the equipment necessary for its successful operation. The last year has been no exception in this respect.

Several years ago windmills were first used in isolated areas to drive generators to provide electrical current for cathodic protection of pipe lines. One disadvantage of this type of unit was the fact that in certain localities, because of low wind velocity, the unit was out of operation for long periods of time, and insufficient electrical current was generated. During the last year this difficulty has been overcome.[1] An arrangement has been worked out whereby when the wind velocity is insufficient to drive the windmill two large storage batteries are cut into the system to provide electric current. This set-up involves the use of two windmills and two storage batteries at each installation. One of the windchargers is a 6-volt unit, the other a 20-volt. The large unit is employed to charge the pipe when wind velocity is two miles or more per hour. The 6-volt unit charges the two batteries and when the wind velocity declines to less than two miles an hour and the 20-volt windcharger ceases operating the batteries are cut in. The batteries are of 120 amp-hr. each and are connected in parallel to give a total of 240 amp-hr. on a fully-charged battery. Since this type of unit has been adopted it has been found to give ample protection to the pipe line at all times.

Another cathodic protection unit of interest is that installed by a gas pipe line company in the Gulf Coast area.[2] In this installation a rotary type engine, which provided the power, was made to run on the pressure drop around a large regulator at a point of high delivery, consuming no gas. To devise this unit a small rotary engine designed to operate on air and steam was redesigned to operate on natural gas at the pressure drop available. By machining to 0.002 in. the clearance between the rotor and the cylinder wall and truing up to where it would drive

[1] "Improved Operation of Windchargers for Cathodic Protection of Pipe Lines," by Dave Harrell, *The Petroleum Engineer*, March, 1938.

[2] "Rotary Engine Drives Cathodic Protection Generator," by Dave Harrell, *The Petroleum Engineer*, October, 1937.

a 2.4-kw., 1750-r.p.m. generator at maximum rated load, the engine was made to operate in the desired manner. Also, a 2-in. by-pass around the regulator was provided, this size having been found essential after a 1-in. by-pass had been tried.

Important to the success of cathodic protection is the proper installation of ground beds.[3,4] The selection of the proper site for the ground bed is requisite. Usually the soil having the lowest resistance is preferred. An exception is with respect to sandy soil and clay. Even though the sandy soil may have the lower resistance better results are obtained when the ground bed is placed in clay.

Ground beds are of two types: horizontal and vertical, the latter affording the greater advantages. Earth drills, on the order of core-drilling machines, have been devised for drilling the holes incident to the installation of vertical ground beds. Usually ten to twelve holes having 20-ft. centers are drilled to a depth of 20 feet. The vertical pipes placed in these holes are connected by a cable welded across the top. The drill, fastened to the floor of the truck by four bolts, can be installed and removed easily.

In passing it should be mentioned that pipe-line coatings have undergone many improvements as a result of the widespread use of cathodic protection because many of the older types of coatings were found valueless for use on pipe protected cathodically.

Pipe Line Construction

Development of a weldable line pipe having high tensile strength has been a great aid in pipe-line construction. Constant refinements in the art of welding also are playing a significant role in this important work. New equipment and improvements in technique almost yearly increase the speed with which joints of pipe can be welded. The extent to which lines were laid by the "stove-pipe" method showed a marked increase during the year. This method, which consists of laying and welding each joint individually, is adaptable to both electric and oxy-acetylene welding procedures. It is favored over the "firing line" type of construction in swampy, rough, and muddy areas because it eliminates the line-up crew, which cannot work advantageously under such conditions. It is also faster in such areas and effects an economy because of the one less working crew required.

During the year, in the field of oxy-acetylene welding, two new welding tips were introduced, a 4-flame tip for making position welds and a 6-flame tip for making rolling welds. The former, in addition to the principal welding flame, provides two flames for preheating the vee and a fourth flame for preheating the rod. In design the 6-flame tip is similar to the 4-flame, the only difference being that the former has four flames preheating the walls of the pipe.

A recent addition to arc-welding equipment is a Diesel-engine welder, in 300- and 400-amp. sizes. This Diesel-engine-driven arc-welder was tested on construction jobs during the year, after which it was made available commercially.

Crude Oil Pumping

Light-weight, high-speed engines for powering pumping equipment continue to be favored for field use. Their portability makes them highly desirable for this type of work and the economy of their initial investment is also a factor in their favor. Within recent months such units have been made available in improved designs that afford a range in pumping capacity of 2400 to 30,000 bbl. per day. Units capable of pumping 30,000 bbl. per day are of such compactness that they can be mounted on skids and moved to the desired location by truck. Certain designs, embodying the latest metallurgical developments, will give continuous service performance for four- to five-year periods without major overhauls.

Another outstanding advancement has been the development of a new rotary pump. This unit will merely be mentioned here as an article giving the details of its design and operation appears elsewhere in this issue of *The Petroleum Engineer*.

A type of field station of unusual design, and one embodying an arrangement of equipment new in gathering systems, is in operation in the Rodessa field.[5] The arrangement can be used either with reciprocating or centrifugal pumps and in field or main line stations. It is, in reality, a self-priming unit and involves the use of a priming tank, a centrifugal discharge pump, and a vacuum pump as the principal equipment. When voids, caused by gas or air entering the line, occur ahead of the station, instead of the discharge pump going out of service the vacuum pump begins operating and expels the gas or air that has accumulated in the priming tank. When it has performed its function the vacuum pump is automatically shut off. This station has been successful in maintaining continuous pumping service with a gauger periodically making a routine checkup the only operator required.

Considerable interest has been manifest by engine owners in the operation, on the full Diesel principle, of the two-cycle Diesel engine using natural gas as fuel. Although this practice is still in the experimental stage, insofar as the oil industry is concerned, the Municipal Electric Plant at Lubbock, Texas, has operated such a unit successfully for almost two years.[6] The engine will burn either gas or oil fuel without any major changes being made in the engine, the fuel being burned on the Diesel cycle and with maximum efficiency. Due to the fact that at this particular plant the natural gas used as fuel contains about 75 percent methane and the ignition on straight gas is somewhat erratic, a small amount of fuel oil is injected with the gas as a stabilizing medium. This oil is delivered to the bottom of the fuel-valve assembly and is injected into the power cylinder by the gas fuel. The amount of oil thus used accounts for about five percent of the total B.t.u. of the fuel consumed at full load.

Metering Crude Oil

The closed system of handling crude oil to prevent evaporation losses has made desirable the use of meters to measure the oil without the necessity of opening tanks to run a gauge line. Although meters are now used for some purposes on pipe-line systems, manufacturers are working on the problem of making them consistently accurate so they will be generally acceptable for measuring crude oil.

ACKNOWLEDGMENTS

The writer wishes to make acknowledgment to the following for suggestions and information: J. L. Culbertson, chief engineer, The Texas Pipe Line Company; J. L. Latimer, vice-president and manager, Magnolia Pipe Line Company; B. P. Sibole, vice-president, Stanolind Pipe Line Company; C. M. Rosebrugh, chief engineer, Gulf Refining Company, Houston Pipe Line Division; W. C. Kinsolving, operating superintendent East Texas lines, Sun Pipe Line Company; and Stanley Learned, chief engineer, Phillips Petroleum Company.

[3] "Cathodic Protection of Pipe Lines," by Starr Thayer, *The Petroleum Engineer*, July, 1937.

[4] "Ground Beds for Use in Cathodically Protecting Buried Pipe Lines," by S. U. McGary, *The Petroleum Engineer*, December, 1937.

[5] "Electric Field Pipe Line Station Operates Automatically," by Frank H. Love, *The Petroleum Engineer*, April, 1938.

[6] "Operating Experiences With Gas-Fuel Diesel Engines," by J. J. Graham. Paper presented at Eleventh National Oil and Gas Power Meeting of the American Society of Mechanical Engineers, Dallas, Texas, June 6-9, 1938.

Newer Trends and Methods in Geophysical Petroleum Exploration

By J. BRIAN EBY*

WHEREVER and whenever the problems of oil exploration are discussed some question naturally arises regarding the evaluation of methods as used in the past and present and what the future may have in store. In these same columns early last year (February, 1937, issue) several authors, including the writer, discussed at some length the better known methods of geophysics then in use, especially the torsion balance and seismograph. In the following pages it is hoped first, to show briefly the relation of geology and geophysics to oil exploration and second, to discuss some of the new methods of geophysical exploration. Maps and detailed data concerning the electrical or "Eltran" method and the soil analysis method will be given.

Oil field discoveries can be classified roughly into three groups: first, those found as a result of random or wildcat drilling, second, those found as a result of drilling on geological prospects, and third, those found as a result of drilling on geophysical prospects. In a recent classification[1] of oil-field discoveries from 1922 to 1936 inclusive, it was attempted to separate each of the 541 major oil fields found in this period according to the method by which each was found. The separation of these major fields by years and the proper credit to wildcatting, geology, and geophysics is shown in Fig. 1. Only oil-field discoveries that represented a million or more bbl. of oil actually in sight have been considered and classified as major oil fields. The great preponderance of scientific discoveries, meaning geological and geophysical as opposed to wildcat discoveries, is clearly evident.

As discovery of the great East Texas oil field is credited to wildcatting, Fig. 2 is arranged to show the cumulative ultimate production discovered by each of the three methods annually. On this graph the real importance of the East Texas discovery to wildcatting cannot be overlooked. It alone is equivalent to 4000 discoveries of one million bbl. each.

The petroleum reserves of the same fields and their relation to the national oil reserve is shown in Figs. 3 and 4. The major national oil field discoveries for 1937 have not been classified according to the method of discovery. It is considered advisable to await the development of these newer discoveries to obtain information concerning their true size and reserve.

Geology, deeper drilling, and geophysics are all three playing an important role in the development of improved exploration methods. Levorsen[2] has clearly indicated newer objectives for geologic research, and has discussed stratigraphic traps and suggestions for finding them. The mechanical and production engineers have so advanced the art of deep drilling that it is now possible to attain the extraordinary depth of slightly more than 15,000 ft., as in a California well completed in April. The trend to deeper drilling is clearly shown in Fig. 5.

The geophysicist is keenly aware of the changing order. The need and demand for newer methods of geophysical exploration are not going unheeded. Among these newer developments the layman in the oil business probably hears about Eltran and the analyses for soil hydrocarbons. Other than technical literature there is almost nothing in print concerning any phase of these two interesting methods of geophysical research.

The word "Eltran" is a contraction of the words "electrical transients" and refers directly, therefore, to this particular electrical method of prospecting. It was introduced into this country by Dr. L. W. Blau and his associates[3] of the geophysical staff of the Humble Oil and Refining Company. Dr. E. E. Rosaire, well-known independent Houston geophysicist, founder and owner of Subterrex, a geophysical exploration organization specializing in Eltran and soil analysis for ethane, by permitting the use of much of his experimental data has made the following discussion possible.

Eltran anomalies are said to represent the electrical expression of the shallow mineralization that occurs over buried structure. This mineralization over deep-seated structures was noticeable in the early days of Gulf Coast drilling because of the induration or

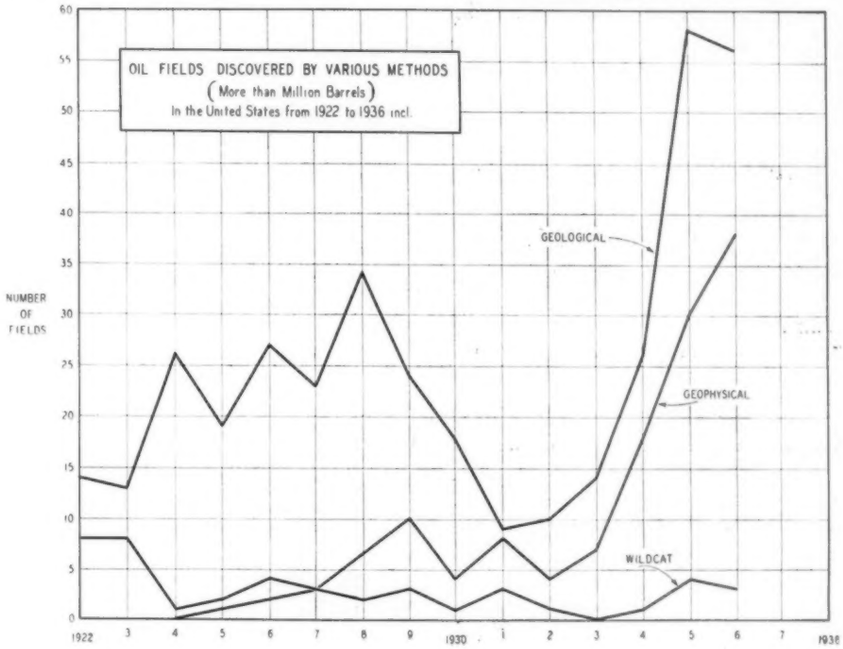


Fig. 1

*Geologist, 906 Sterling Bldg., Houston, Texas.

[1]A more nearly complete discussion of technical progress in oil exploration over the last quarter century is included in a report entitled, "Technology, Employment, and Output Per Man in Oil and Gas Production," now in preparation by the National Research Project—WPA in cooperation with the United States Bureau of Mines. The author collaborated in preparing the section of this report on oil exploration and is indebted to the directors of the study for permission to present Figs. 1, 2, 3, 4, and 5. These illustrations are preliminary and subject to revision.

[2]A. I. Levorsen, "Stratigraphic Versus Structural Accumulation," A.A.P.G. Bull., Vol. 20, No. 5 (May, 1936), pp. 521-30.

[3]Louis Statham, "Electrical Earth Transients in Geophysical Prospecting," Geophysics, Vol. 1, No. 2, June, 1936, pp. 271-77.

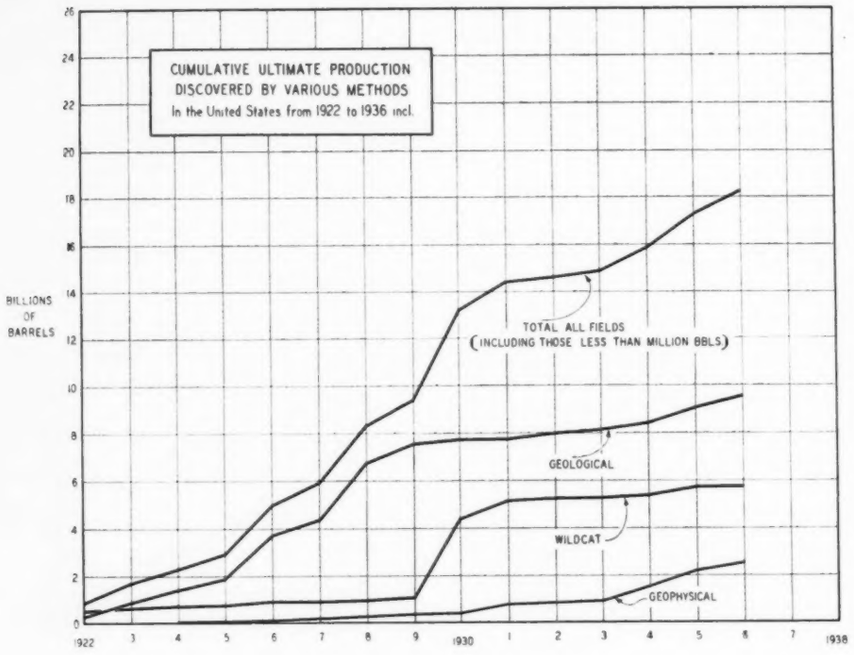


Fig. 2

hardening of the sediments over the structure. Later this shallow mineralization was passed by without notice on account of the use of heavy-duty rigs and the use of rock bits. The high speeds, or so-called fast shots, in the refraction seismograph campaign of 1924-1931, represented the acoustical expression of this mineralization. For example, fast shots by seismograph were observed over such deep-seated, low-relief structures as Conroe, Van Vleck, and Turtle Bay in the Gulf Coast, and Monument, Tubbs Ranch, and Means in the Permian Basin. It is believed that this mineralization affects the distribution of hydro-carbons seeping from the underlying deposit, resulting in the "halo" pattern of gas seeps that was responsible for the discovery of Goose Creek in 1906 and was also observed at Humble, Sour Lake, and several other fields prior to their discovery. This mineralization appears to be a good index of the presence and lateral extent of structures of very low relief.

An example of an Eltran map of structure is given by the accompanying map of a portion of Yoakum and Cochran counties, Texas (Fig. 6). This map shows the results of approximately 140 miles of Eltran traverse from the Wasson oil field in Gaines County northward to the central part of Cochran County. The relationship between the producing fields, dry holes, and the electrical contours is regarded as significant. In order to comprehend the meaning of these contours it is well to discuss in detail the field operations of the Eltran and the method of obtaining and evaluating the data upon which the contours are based. The following discussion of Eltran operations and methods is taken largely from a manual prepared by Dr. Rosaire.

The field crew of an Eltran party consists of a minimum of eight men, using four cars and two or three trailers. The surveyor scouts the roads in advance of the crew, reporting on the presence of pipe lines, high-tension power lines, railroads, cased wells, hog-proof wire fences, and any other grounded metallic conductors that might result in an artificial distortion of the normal distribution of the electrical current when applied to the earth in the immediate vicinity. The exploration is then planned along favorable profiles, the surveyor procuring the permits, if needed, in advance of the field men.

Next, the surveyor and rodman, in a field pickup, lay out the various lines of electrode stations, generally at 500-ft. intervals. The alternate stations, spaced at 1000-ft. intervals, are numbered integrally (101, 102, etc.) and the intervening electrodes, spaced at 500-ft. intervals from the integer stations, are usually labeled as half stations (101½, 102½, etc.). These are all surveyed with chain, alidade, and plane table, and transferred to a map for later presentation of the data.

In dry terrain, where normally some difficulty would be noticed in making good electrical contact with the ground to get sufficient current therein, two holediggers in another field pickup, sometimes using a farm trailer, follow the surveyor. At each electrode station they dig holes two to eight ft. deep, depending upon the ease of the digging. Samples of soil from the bottom of each hole are saved, in duplicate, in properly numbered pint-size glass jars, for possible later analysis by the laboratory. Next, the hole is salted, by filling, wholly or partly, with salt water. Where possible, nitrate of soda is used to avoid protests from farmers. This soaks into the surrounding soil, thereby decreasing the electrical resistivity of the soil around this (future) electrode hole. Shortly there-

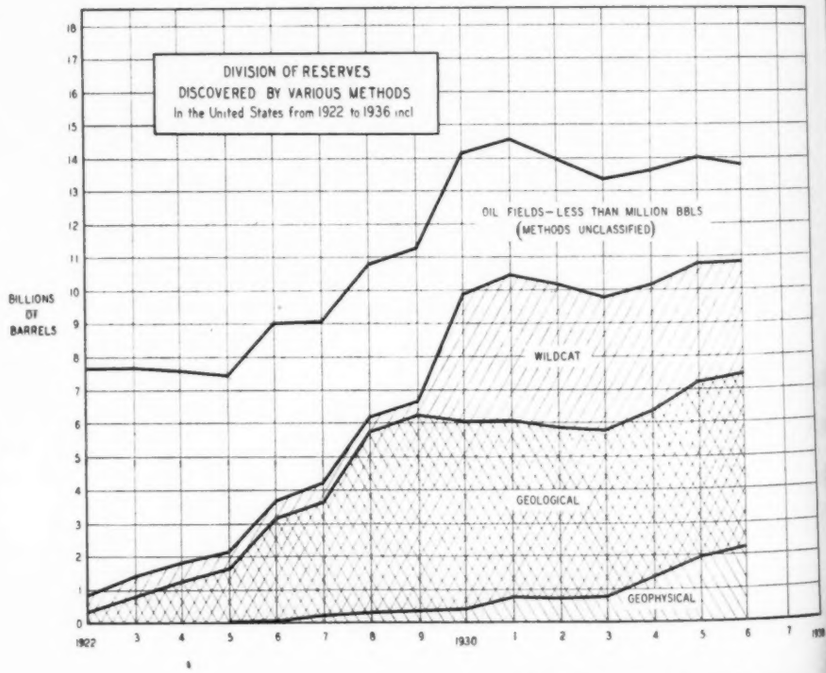


Fig. 3

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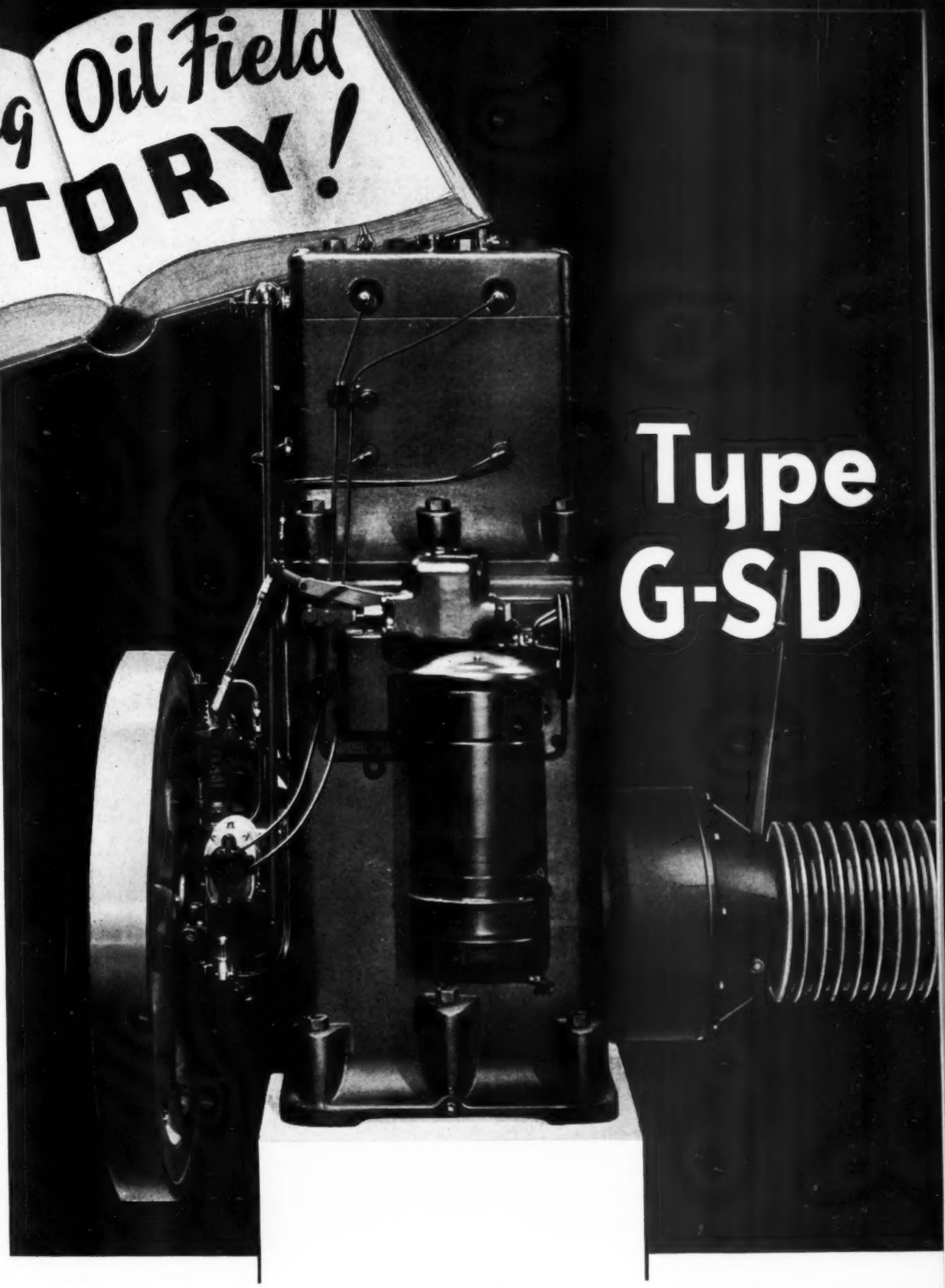

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after these holes are used by the technical crew for the insertion of the electrodes.

The technical crew consists of the observer (party chief) and his electrode man, and the generator man and his rear electrode man. The observer is in charge of the recording unit, which is generally mounted in a trailer drawn by a Ford car, and the generator man is in charge of the generator unit, which also is generally mounted in a trailer, and drawn by another car. These trailers are used because of the frequent necessity for operating off the roads, or for closer detail, or because, frequently, the roads cannot be used because of parallel pipe lines, high-tension lines, railroads, and grounded or charged fences, which prevent taking any electrical data. In order to expedite operations off the roads, each trailer can be equipped with a wagon tongue so that mules or horses can be hitched directly thereto. Both units are equipped with 1000 ft. of cable for attachment to a second electrode, one being placed at the trailer. Radio communication between the trailers is, or soon will be, standard equipment.

The usual field operations are as follows: Assume a straight road, along which electrical stations 1, 1½, 2, 2½, 3, 3½, etc., have been laid out at intervals of 500 feet. The rear current electrode is placed at station 1, the generator unit and the front current electrode at station 2, connected by the current cable. The rear potential electrode is at station 2½, and the recording unit and first potential electrode are at station 3½, connected by the potential cable.

The generator unit begins operating, putting an electric current directly into the ground through the front and rear current electrodes at stations 2 and 1, respectively. Five repeated observations are made by the observer, using the separation (center spread) of 500 ft. as outlined above. Next the observer signals his rear electrode man to disconnect the potential cable and pull up the rear potential electrode, doing the same for the front potential electrode. The recording unit is then moved 500 ft. to station 4, dragging the potential cable, where the front potential electrode is placed, while the helper advances to station 3 where he plants the rear potential electrode, to which he again connects the rear end of the potential cable.

After taking a set of observations with the (then) separation or center spread of 1000 ft. (the generator unit has not moved), the same operation is repeated, so that, with a second advance of 500 ft., data are obtained for separation or center spread between the rear potential electrode and first current electrode of 1500 feet.

Usually, no more than three center spreads are taken for each generator position. Frequently only two are taken and sometimes only one; however, if two or three have been indicated for each generator position, upon completion of the two or three center spreads the recording unit remains stationary, and the generator unit advances 1000 ft., after which this sequence is repeated.

If only one center spread is indicated, as in a reconnaissance program in familiar territory, both units move forward together by an amount equal to the indicated center spread. This type of operation naturally is the fastest.

The observations at each recorder setup usually consist of photographing the incoming e.m.f. between the two potential electrodes, and then making at least five determinations of the reciprocal time constant by getting a null balance on the incoming e.m.f., or reducing this incoming e.m.f. to a standard wave form. Later, by means of a simple curve, these data are converted into the indices used for plotting on the report map. Obviously, if necessary, these data can be made available from setup to setup.

The time required for photographing and making the usual balance is never more than five minutes, frequently only two or three. The daily coverage, then, is ordinarily determined by the time required to move between setups and is dependent entirely on the terrain. In the Gulf Coast, the maximum speed attained last year was 55 setups in one day. Recently, while operating in the Permian Basin, a crew made a maximum of 116 setups in one day. Such performances as these are, naturally, the exception rather than the rule. Along straight roads, however, 40 to 50 setups a day are not uncommon. Along crooked roads, where "switchbacks" are frequent (to keep the electrode in line) the coverage is naturally reduced. In marsh country, where manual portage is required, the number of setups is much smaller.

As the Eltran anomalies are comparable with the size of the producing area, rather than the actual uplift, a reconnaissance Eltran survey should be based on a grid of lines at intervals not exceeding one mile. The field crew should be prepared, however, to increase the survey density to a grid of lines at intervals of not more than one-half mile as soon as even a suggestion of an anomaly has been indicated.

The actual anomalies are much more localized and distinct than are the reflection anomalies. With this greater localization, of course, goes the greater advantage of localization in leasing. A reflection anomaly may require leasing 5000 acres to insure complete control of 1000 possible productive acres, whereas the lease block based on Eltran anomaly need be only about 1500 acres or 2000 acres at most to insure the same margin of safety.

As described, the field setup comprises two current electrodes, spaced 1000 ft. apart, in line with two poten-

(Continued on Page 37)

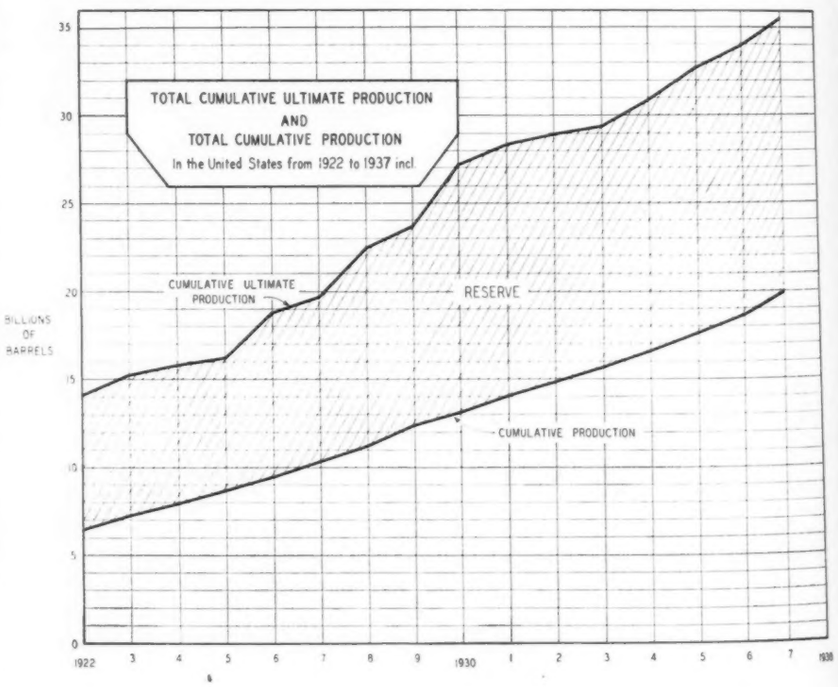
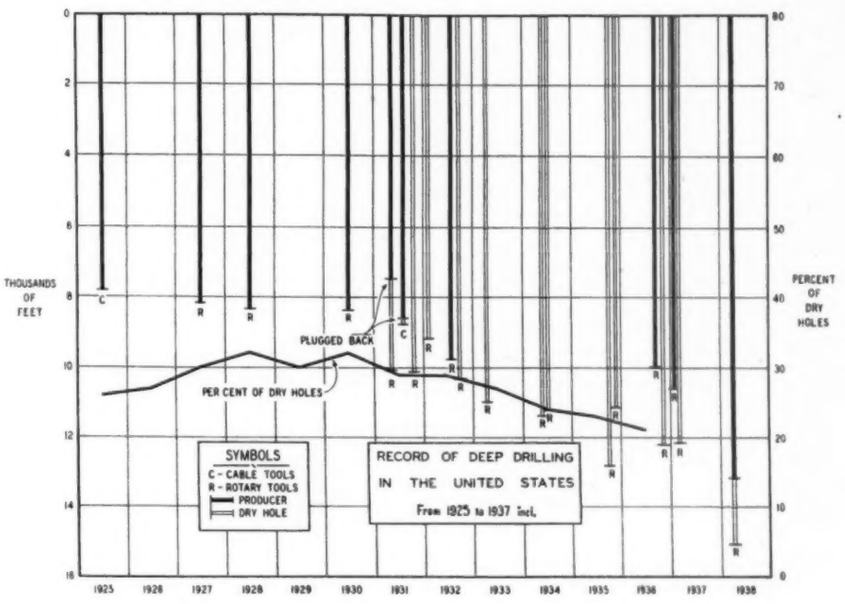


Fig. 4

Fig. 5



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tial electrodes, also spaced 1000 ft. apart, separation between the inner current and potential electrodes being 500 to 1500 feet. As the anomalies remaining to be found become less and less distinct, this center separation will undergo a corresponding increase, eventually, perhaps, to as much as one mile.

The Subterrex modification of the original Eltran method involves putting a square current impulse into the ground through the current electrodes, repeated continuously at frequencies ranging from 10 to 100 cycles per second.

Because of greater attenuation of the higher frequencies by the earth, the e.m.f. observed at the potential electrodes is no longer square, but rounded at the corner, eventually reaching a steady value that is a function of both the current passing through the two current electrodes and the resistivity of the earth. The rounded form of the observed e.m.f. approximates an exponential rise, and to that extent can be approximated by a network consisting of known resistances, capacities, and inductances. By opposing the observed e.m.f. with e.m.f. generated locally, the characteristics of the observed e.m.f. can be determined to the extent that a null balance can be reached.

The time constant of such a network, used for generating the opposing e.m.f., is defined as the time required for a given voltage at the terminals of that network to drop to $1/\varepsilon$ of the original, steady state value of the original voltage applied to the terminals, after the application of this steady state voltage has been interrupted. The ε in question is the base of the natural system of logarithms, and is approximately 2.72. This time constant is measured in seconds, and in most of the exploration that has been done ranges from 0.002 to 0.01 second.

If the reciprocal of this time constant is used, then the value of the R.T.C. (reciprocal time constant in reciprocal seconds) rises as higher earth resistivities are encountered, and so is preferred to the time constant itself, for the resistivity of the earth is being considered rather than the conductivity; also, it has been observed that higher R.T.C.'s occur over structure than off structure, and it is natural to use as an index units that are high over structure.

It has been found, however, that the R.T.C. itself is not so satisfactory, graphically, as its logarithm. From experience, it is found that a change in the R.T.C. from 100 reciprocal seconds to 120 reciprocal seconds is just as important, economically, as a change from 500 reciprocal seconds to 600 reciprocal seconds. If a uniform contour interval is used, this distinction is best shown by the use of log R.T.C.'s rather than the R.T.C.'s themselves. Thus, when a contour interval of 0.05 is used for a map based on log R.T.C.'s, each closed contour represents approximately a five percent change in the actual R.T.C.

The resistivity of the earth tends to decrease, generally, with depth. For the longer center spreads, the effective penetration is greater, and the effective resistivity is less. Thus, the general levels of the data for the longer center spreads are lower, for the effective penetration is greater. It is interesting to note, however, that Eltran anomalies usually increase in magnitude (more closed contours indicate greater percentage changes) as the center spreads are increased. This is true within the limits of present field experiences.

The use of two or more center spreads also helps to differentiate between "real" and "spurious" Eltran anomalies resulting from undesirable proximity to metallic conductors such as pipe lines, etc., and the R.T.C. actually increases with increasing center spreads, just the reverse of what should happen in the normal earth; also, such spurious anomalies sometimes are not noticeable at all center spreads, whereas a "real" Eltran anomaly should be present, in some degree at least, on all the spreads used, or should change in value smoothly rather than abruptly.

By photographing the e.m.f. observed at the two potential electrodes, a permanent record is made, which is susceptible to independent analysis. Frequently, very complicated shapes of this e.m.f. are observed, which are not readily analyzed by the usual methods of balancing. In such cases, the correct solution can be made only by an inspection of the actual photographs. In the final analysis, given satisfactory photographs, the field data will always be inferior to the data obtained by an analysis of the photographic data. In the final interpretation, both the visual field analysis and the actual photographs are given proper weight. In most work, however, the data from the visual balances alone are sufficient for the direction of the next day's work, and often suffice for lease purposes.

Increasing in importance as a method of exploration is the analysis of soils for significant hydrocarbon gases indicating the presence of oil-bearing structures. The map of the Hastings oil field, Brazoria and Galveston counties, Texas, shows a preliminary soil analysis survey of this field by Subterrex (Fig. 7).

Prospecting by the search for visible oil and gas seeps has a record of past successes, as, for example, the "Chapapote" (asphalt) seeps along the Golden Lane in Mexico, and the gas escapes observed at Humble, Spindletop, and Goose Creek prior to the discovery of oil. This technique was limited to visible seeps, and gas escapes were visible only in areas covered by water.

A parallel might be drawn in the development of paleontological methods for identification of sedimentary layers. The early use of the method depended on discovery and identification of fossils visible to the naked eye, i.e., *macro*paleontology. With the recognition that the smaller fossils were not only as satisfactory, but also present in much greater numbers, the

development of *micro*paleontological methods was begun, and that technique is now regarded as the fundamental method for identification of strata.

So, in the technique of prospecting for hydrocarbons that escape from, and so indicate the presence of, buried deposits, it is natural to expect that, if "macro" gas and oil escapes proved to be of prospecting importance, then "micro" gas and oil escapes should prove to be just as usable, and that a change in prospecting technique should be just as sound fundamentally as the development of micropaleontology. The real problem was not whether the new technique would be useful, but whether the new technique could be developed.

In the development of this "micro" technique, Substerrex has anticipated that the soil itself might be a better accumulator of the escaping hydrocarbons than are the interstices in the soil. Having in mind the preferential adsorption of finely-divided particles for the more complicated molecules, as indicated by the action of the activated charcoal in gas masks in adsorbing poison gases, the phenomenon of such adsorption of the escaping hydrocarbons was sought in the soil particles themselves.

The technique, then, is based on obtaining properly-selected samples of soil, treating that soil in the laboratory to volatilize the adsorbed hydrocarbons, separating the ethane, which is the fundamentally significant constituent, because it has never been found as an end product of the bacterial decomposition of organic matter, whereas methane is the usual end product, and measuring the amount of ethane in relation to the amount of soil comprising the sample. By weight, the amount of ethane found usually ranges from 0 to 200 parts per billion parts of soil.

These "ethane counts", in so-called "billigrams", are then spotted on the map of sample locations, and the data studied for significant patterns. (Fig. 7.)

Two significant patterns are recognized at present. One group is narrow and elongate, coinciding with the surface traces of faults that intersect reservoirs. The other group takes the form of rings, or halos, inside and outside of which low values ("ethane counts") are found. The recognition of such a pattern of "macro" gas escapes led to the discovery of production in the Goose Creek oil field, for inside the halo no gas escapes were observed and outside the halo no production was found. It is interesting to note that, although about 30,000,000 bbl. of oil were produced from that field from sands as shallow as 1400 ft., the observed gas escapes were around the edges of the field rather than over the top of the field. About the same time, similar patterns of gas escapes were noticed at Humble, Spindletop, Sour Lake, and Pierce Junction prior to the discovery of oil at these structures.

It is assumed that this halo results from vertical migration of the hydrocarbons through faults and fissures existing over structure. Because of the shallow secondary mineralization over buried structure, (also responsible for the sedimentary induration often referred to as "dome digging," for the "fast shots" observed in refraction prospecting, and for the electrical anomalies found by the recently introduced Eltran method), these fractures and fissures tend to be sealed over the top of the structure, so that the leakage that takes place is concentrated around the edges of the mineralized zone in the form of a ring, or halo.

In many areas, a halo is observed that is close or even tangent to a narrow elongate anomaly. This is true where a fault, having its origin in or intersecting the producing area, reaches the surface. For a normal fault, the halo lies on the down-thrown side relative to the surface trace.

This halo distribution has been observed not only in the Gulf Coast of Texas and Louisiana, but also in the Permian Basin and in the Mid-Continent, so that it is considered a phenomenon associated with producing structure.

It is quite probable that these two are not the only significant patterns that will be observed. As a result of

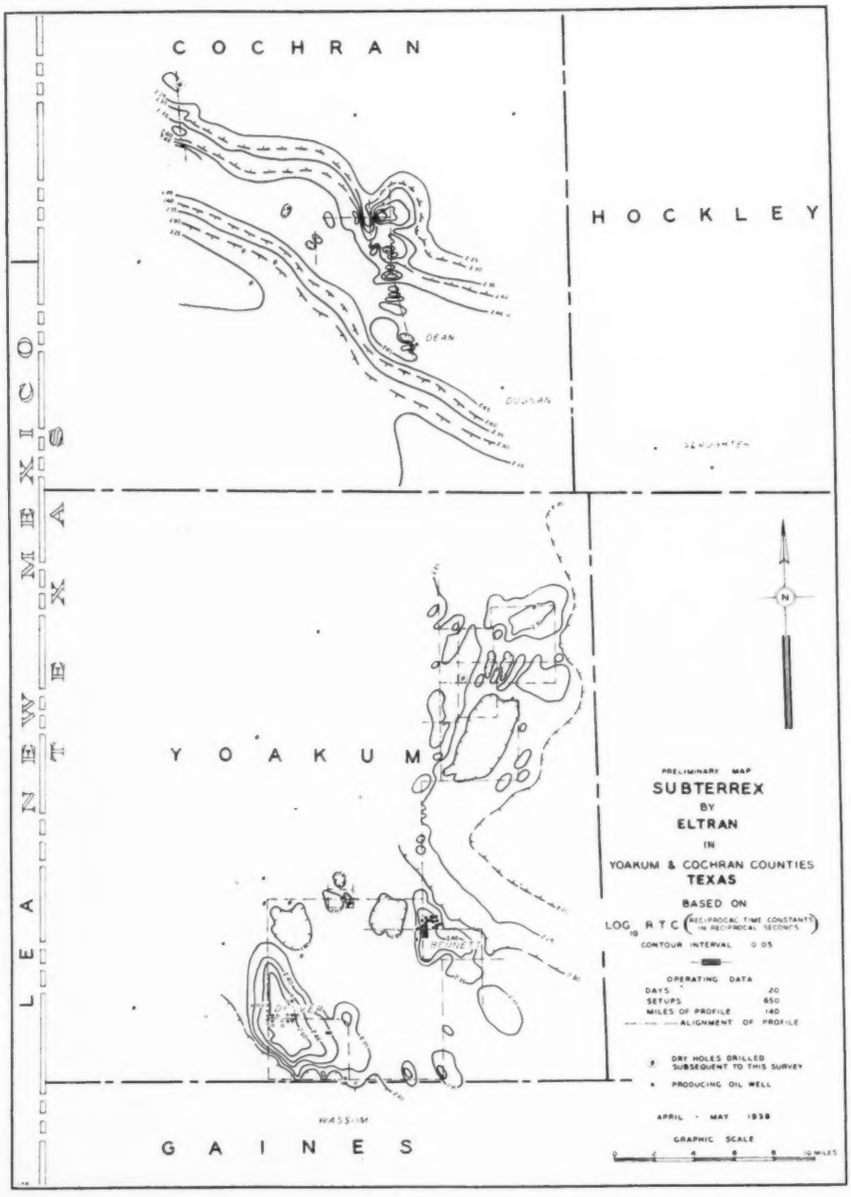
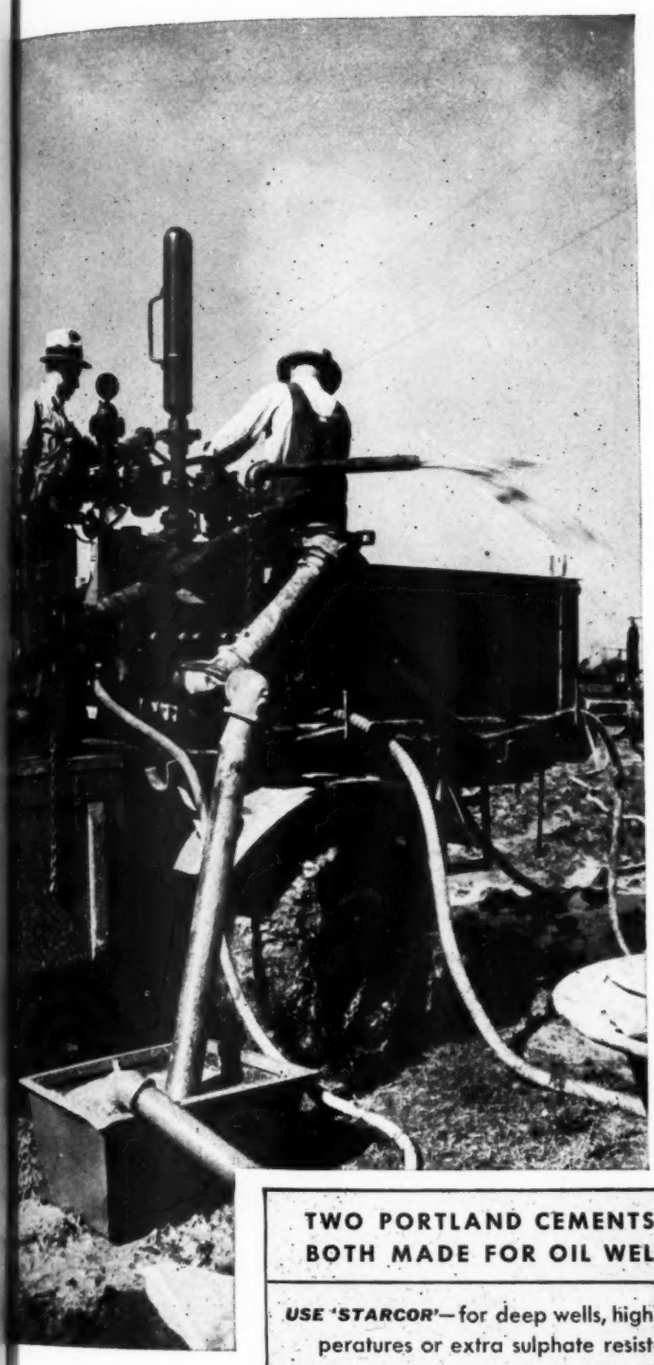


Fig. 6

'SQUEEZE' JOBS



'STARCOR'S LOW VISCOSITY A BIG HELP

IT TAKES an experienced operator to do a successful double-squeeze job. And it takes a cement that has both low viscosity and high gel strength. A job in the Refugio Field shows how well 'Starcor' meets these requirements.

This well had been producing since 1932, from sand below the 4700-ft. level. Well was plugged—casing was perforated at 4600 and 4680 ft.—salt water at both points. A double-squeeze was then made. That required an 80-ft. wall of perfect cement around the casing. They took no chances—'Starcor' was used.

'Starcor's low viscosity made it possible to pump 80 sacks of 15.8-lb. slurry into the formation below a cement retainer at 4660 ft., with pump pressures 1800 lbs. and lower. Then, 40 sacks of 'Starcor' in a 15-lb. mix were pumped into the formation through the top perforations. When casing was perforated at oil sand, they got an oil-flow free from salt water contamination.

'Starcor'* is specially adapted for squeeze, plug-back and re-conditioning jobs, as well as for deep holes, high temperatures and extra sulphate-water resistance. For wells of normal depth, use 'Incor'*, with its 10-year record of success in all of the principal fields. Your dealer stocks both cements for immediate service.

*Reg. U. S. Pat. Off.

TWO PORTLAND CEMENTS—BOTH MADE FOR OIL WELLS

USE 'STARCOR'—for deep wells, high temperatures or extra sulphate resistance.

USE 'INCOR'—for wells of moderate depth.

Subterrex experience to date, there is justification for recommending development on a well-defined "halo," although as yet experience is insufficient to establish the relationship between the observed "ethane counts" and the amount of production to be expected. In other words, predictions are qualitative as to the amount of the accumulation from which the observed leakage is taking place, but are much more nearly quantitative with regard to the areal extent over which production can be expected.

Summarizing the exploratory plan of both Eltran and soil analyses, it may be pointed out that an increasingly greater percentage of the undiscovered oil fields will be characterized by vanishingly low relief. When only structures of low relief remain to be found, our presently-accepted evidence for buried structure may no longer be the best criterion for its existence. The usefulness of these two new methods is predicated upon the hypothesis that, in such low-relief traps, leaking hydrocarbons and shallow mineralization are better clues than the evidence for *relief* indicated by other methods.

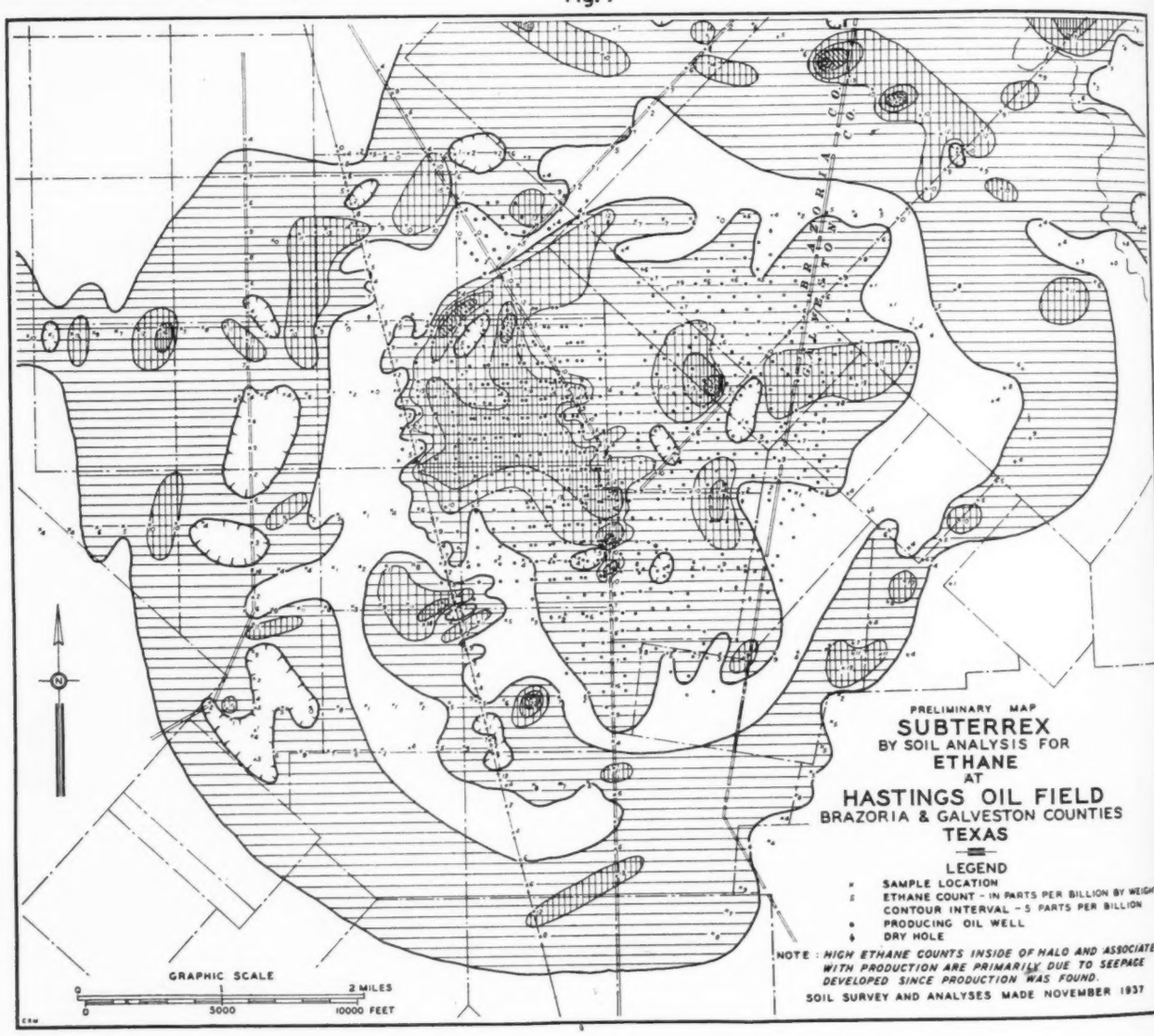
The older methods of geophysics, especially the reflection seismograph, are still in widespread use. On January 1, 1934, there were in operation in the United States approximately 75 reflection seismograph crews. By January 1, 1938, due to successful results, the number of crews had increased to about 240. Since that date, however, there has been a definite reduction in the number of parties operating in the field.

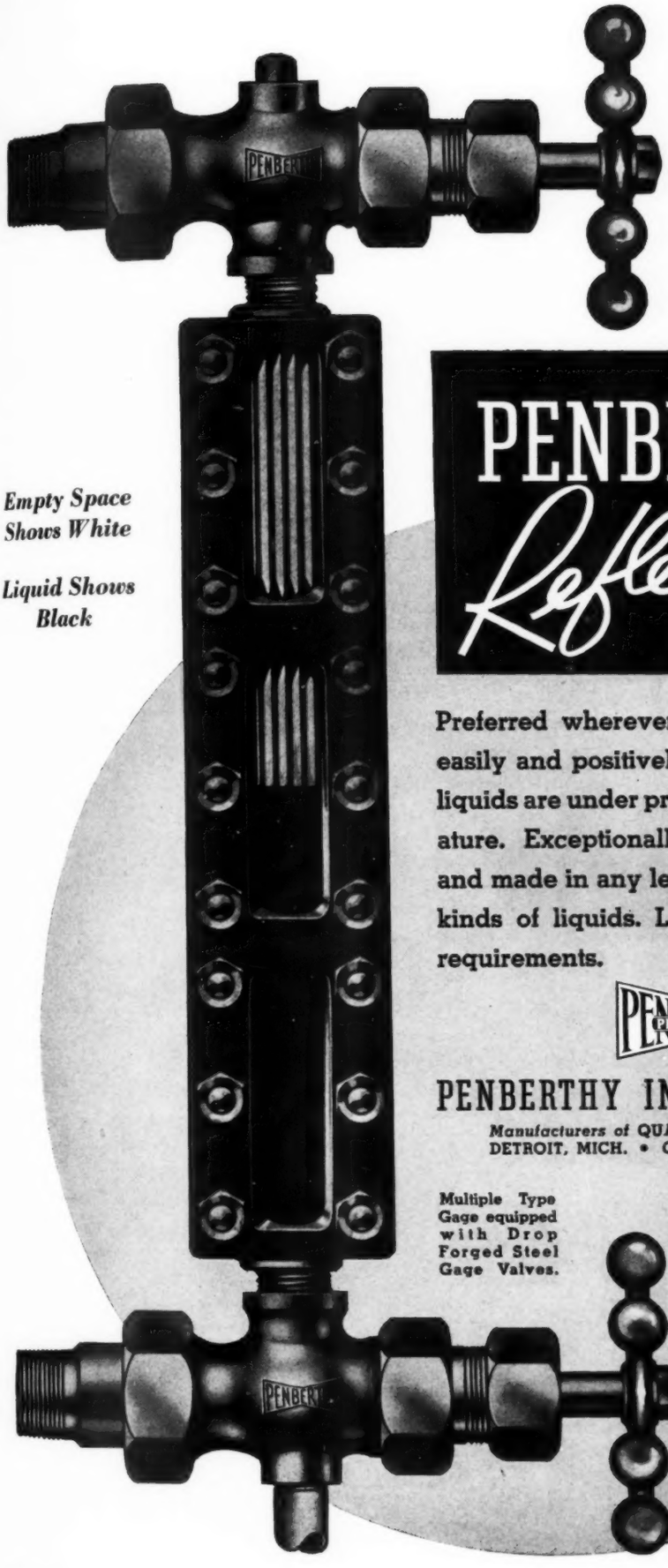
For several years the number of torsion balance crews in operation in the United States has fluctuated between 30 and 50. Within the last six months this manner of exploration has gradually been giving way to the use of the gravimeter (gravitymeter). There has been little change in the status of magnetic or miscellaneous types of investigation in the last few years.

It is interesting to compare costs of the Eltran and soil analysis processes to those of torsion balance and reflection seismograph. Assuming normal dry ground and accessible terrain the Eltran method costs average between $6000 and $7000 per month. A soil analysis survey in ordinary easily accessible country averages between $2000 and $3000 per month, the average cost per single analysis being, therefore, about $9.00. For the sake of comparison, the customary contract cost of reflection seismograph work, also based on average accessible terrain, is $8000 to $10,000 per month. Torsion balance exploration costs vary from $5000 to $8000 per month, depending largely on local conditions.

In closing the author wishes again to point out that Eltran and soil analysis are only two of several new lines of geophysical investigation. They are, however, undoubtedly among the most prominent and give the most promise of immediate success.

Fig. 7


PRELIMINARY MAP
SUBTERREX
BY SOIL ANALYSIS FOR
ETHANE
AT
HASTINGS OIL FIELD
BRAZORIA & GALVESTON COUNTIES
TEXAS
LEGEND
SAMPLE LOCATION
ETHANE COUNT - IN PARTS PER BILLION BY WEIGHT
CONTOUR INTERVAL - 5 PARTS PER BILLION
PRODUCING OIL WELL
DRY HOLE
NOTE : HIGH ETHANE COUNTS INSIDE OF HALO AND ASSOCIATED WITH PRODUCTION ARE PRIMARILY DUE TO SEEPAGE DEVELOPED SINCE PRODUCTION WAS FOUND.
SOIL SURVEY AND ANALYSES MADE NOVEMBER 1937
GRAPHIC SCALE
0 2 MILES
0 5000 10000 FEET



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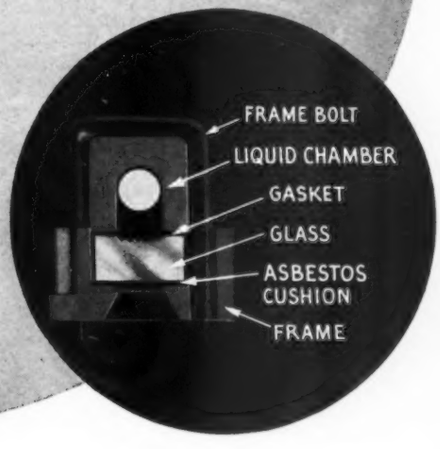

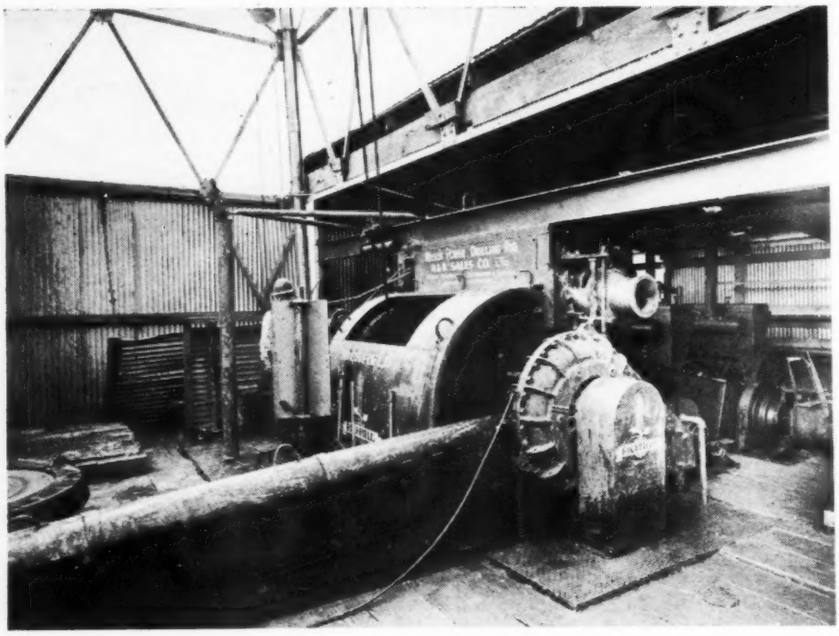

Modern drilling rig in use in California

By
WALLACE A. SAWDON
Petroleum Engineer, Los Angeles

Progress In Drilling Technique In California

DEFINITE advancements in drilling technique have been made in California during the last 12 months. Interest has naturally focused on the drilling depth record of 15,004 ft. reached in the Continental Oil Company's well at Wasco and in a production depth record of 13,000 ft. set by that well, which followed closely the establishment of the record of 11,302 ft. by Union Oil Company of California at Rio Bravo. Since completion of the Continental well, the Standard Oil Company of California has obtained production in a well drilled to a depth of 11,520 ft. in the Greeley field where the Rio Bravo sand was entered at a depth of 11,419 feet. The Ohio Oil Company has found production below 10,000 ft. in the old Buena Vista gas field.

The drilling of these and other deep fields has proved that obtaining production below 10,000 ft. is now an established practice and the methods and equipment used to complete wells at these depths have demonstrated the adaptability of tools, machinery, and technique in meeting the problems encountered. The practices followed in deep drilling, however, have done more than prove the ability to drill to a depth of 15,000 feet. They have provided data that are applicable to efficient and economical deep-drilling procedure.

Surface equipment for developing the deep fields is naturally the heavy, modern type. Although the 136-ft. derrick is most commonly used, the 176-ft. derrick is found to provide desirable features in operations such as those at Rio Bravo.

The structural steel support for drawworks and engine has become popular with many companies but a unitized rotary rig developed by one operator has probably provided the greatest degree of portability. This construction consists of four units that support respectively the vertical hoisting engine, the drawworks, the rotary table, and the standby drawworks and the vertical steam engine that drives the rotary table or the standby. Maximum portability and a reduction in rigging-up time result.

In some of the San Joaquin Valley fields the derrick and entire rig above the floor are supported by a substructure of structural steel; only the cellar pit is constructed of concrete. This type of construction is especially suitable where the standby hoist is placed below the derrick floor and underfloor rotary drive is used. It has the further advantage of being transportable.

Drawworks are now generally totally enclosed. The largest drawworks are in service in the Rio Bravo field at the present time, the latest there installed being equipped with a 10½-in. shaft. Both the horizontal twin 14-in. by 14-in. and the vertical 12-in. by 12-in. twin-cylinder engines are used to provide drawworks power where steam is employed in deep-drilling operations. Even standby hoists are driven by engines as large as the twin 12-in. by 12-in. type.

As both greater economy and better performance accompany the use of higher steam pressure, the 350-lb. boiler has come into extensive use for drilling in many of the deeper fields. Batteries usually consist of four boilers of this capacity and battery locations are sometimes made to serve four wells consecutively from the one setting.

Superheaters are quite generally used and several types are employed. One of the recent designs is a portable superheated-steam generator that provides greater output by a more effective use of heating surface rather than by increased size. Many of the boiler plants consist of boilers made with superheaters integral with the boilers but some operators prefer the use of a separate superheater for the battery.

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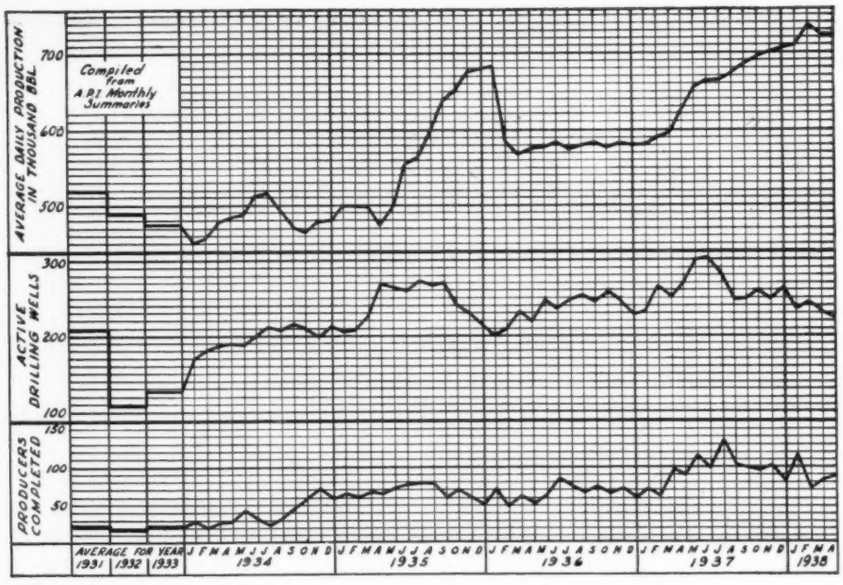


Chart showing production, drilling activity, and completed wells in California

development in drilling technique in California is the use of high rotating speed. Until two months ago the fastest speed was 350 r.p.m. by table drive but recently several companies have used speeds exceeding 400 revolutions per minute. Both the underfloor rotary drive and the individual direct rotary drive situated on the derrick floor have been used to attain these speeds. One company at Rio Bravo carries a weight of 8 to 11 points on the bit at these speeds but others restrict the weight to three to five points when rotating at 400 r.p.m. or more. The character of the formation is an influential factor in determining the weight to be carried and it has been reported that a weight as great as 15 points has been used at a speed exceeding 400 revolutions per minute. There are differences of opinion on the advisability of risking the danger attending this combination of high speed and great weight.

The engines first used with the under-floor rotary drive were horizontal 9-in. by 8-in. twin steam engines. Later the size was increased by one company to 12-in. by 12-in. and it is now reported that this company will next install a 14-in. by 14-in. twin. This will make the prime movers for rig operations consist of a 14-in. by 14-in. for drawworks, a 14-in. by 14-in. set below the derrick floor for the rotary table, and a 12-in. by 12-in. for the auxiliary hoist.

The highest rotating speeds have been attained by the turbo drill[1], which is now drilling just east of the Ten Section field. A rotating speed of 600 r.p.m. is used, and the weight on the bit ranges from 1½ to 4 points, according to the formation being penetrated. On a well previously drilled using this equipment a speed of 1200 r.p.m. was attained but an 8-in. bit was used so the peripheral speed was less than that of the larger bit now drilling. As hole is reduced and a smaller turbo drill employed, the speed of rotation will be increased, because it is governed by the peripheral speed attained by the bit.

Elapsed drilling time has been reduced to an almost unbelievable degree in the wells completed at depths below 11,000 ft. in the Rio Bravo field. Each well there drilled seems to set a record, the latest being reported as having drilled nearly 10,000 ft. in a month. This includes the time spent cementing the surface string but consisted otherwise of time spent drilling open hole, as only two strings are used in this field, the water string being cemented at the top of the sand at a depth just below 11,200 feet.

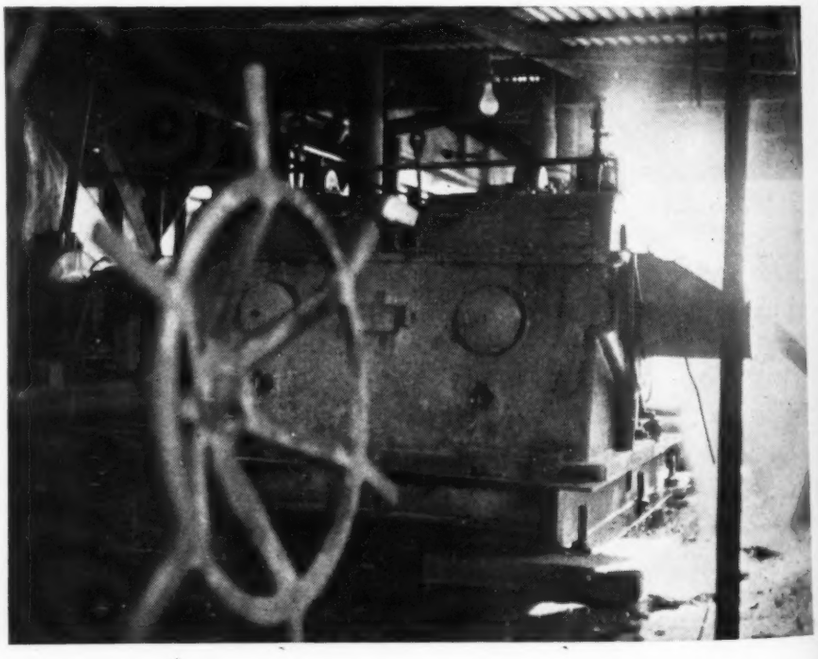
Deflection Control

Controlled vertical drilling is followed extensively in most of the California fields, inclination readings being taken at definite intervals by most of the operators. The coördination of rotating speed and weight carried on the bit, together with the character of the formation being penetrated, the use of proper bit for the formation, and other recognized factors are used to keep the hole vertical.

The use of heavy drill collars and of several drill collars above the bit has been practiced for a number of years. This practice, as an aid to straight drilling, is even more important to those operators using high rotating speed and great weight. It is probable that the weight concentrated just above the bit by weighted tool joints and a series of drill collars has helped greatly in reducing twist-offs as well as helping to keep the hole straight.

The small-diameter instrument that can be run through drill pipe to mea-

[1] "The Turbo Drill — A Development That May Lead to Changes in Present Rotary Drilling Practice." *The Petroleum Engineer*, June, 1938.



This vertical engine powering the rotary table is placed below the derrick floor with the underfloor drive

sure both inclination and direction has come into extensive use in the California fields when both the angle and the direction of drift are to be determined. For inclination only the instrument is either dropped into the drill pipe or run on wire line, the procedure depending on the survey interval, depth of well, and other factors governed by the drilling program and, to a large extent, the preference of the operator. The standard single shot for measurement of inclination and direction is used under many conditions and is generally run for direction and angle control in directional drilling.

In the Wilmington-Long Beach Harbor district directional drilling has been the means of tapping the sand under channels, industrial plants, and schools, and even under surface areas reserved for future plants. There are, moreover, three producing zones in the Wilmington field and some operators drill a hole to each sand from the one location, it being desirable to keep the production separate.

When different sands are drilled by this procedure, one well is drilled vertically and the other two begin from locations set back 150 ft. at the surface. All three holes, however, are completed in their respective sands directly below a common surface location. Other means used to produce the sands individually are discussed in this article under "Well Completion."

The many faults in the Wilmington field have also necessitated the application of directional control. In addition, it has been found necessary to practice controlled vertical drilling in keeping wells within the boundaries of some of the small leases.

Drilling Fluid

It is believed by many operators that considerable credit for the successful completion of the deep wells in California should be given to effective mud control. In drilling most wells the weight of the mud fluid has not exceeded 80 lb. per cu. ft. and there seems to be a tendency toward the use of a weight of 78 pounds. In the Wasco well a 101-lb. mud was used to control high pressure before the 7-in. water string was set and cemented at a depth of 11,573 feet. Below that depth, however, the drilling fluid was only slightly heavier than water and as the well approached the final depth consisted of a mixture of colloidal material and water only.

Characteristics other than weight have probably been given greater consideration during the last year. Several of the major companies in California have made marked advancement in mud control and among the factors that have been given increased attention are viscosity and colloidal properties and their control. The settling of solid matter is controlled and although the mud system of most of the deep and comparatively deep wells is equipped with two vibrating screens, some operators think that three such screens may come into vogue.

In the control of viscosity the use of chemicals has frequently been found advantageous. The results of extensive research work on chemical treatment and on other means of approaching the perfect drilling fluid to meet specific conditions have not been made available for publication. The average viscosity desired might at present be stated as 30 seconds but that used varies both above and below this figure.

The available supply influences the extent to which native mud is used, but a number of companies are using mixtures of colloidal and weight materials without any clay except what may enter the circulating stream as cuttings during drilling. In some fields where no admixture except weight material is added to the fluid made from native mud it is found that thinning with chemicals is frequently necessary. The colloidal properties of a fluid must provide definite attributes and highly colloidal mud is not necessarily the most advantageous.

Circulation is generally provided by two pumps, a third being provided as a standby. The maximum size is 15½ by 8½ by 20 inches. On many rigs two rotary hoses are used.

Coring and Electrical Logging

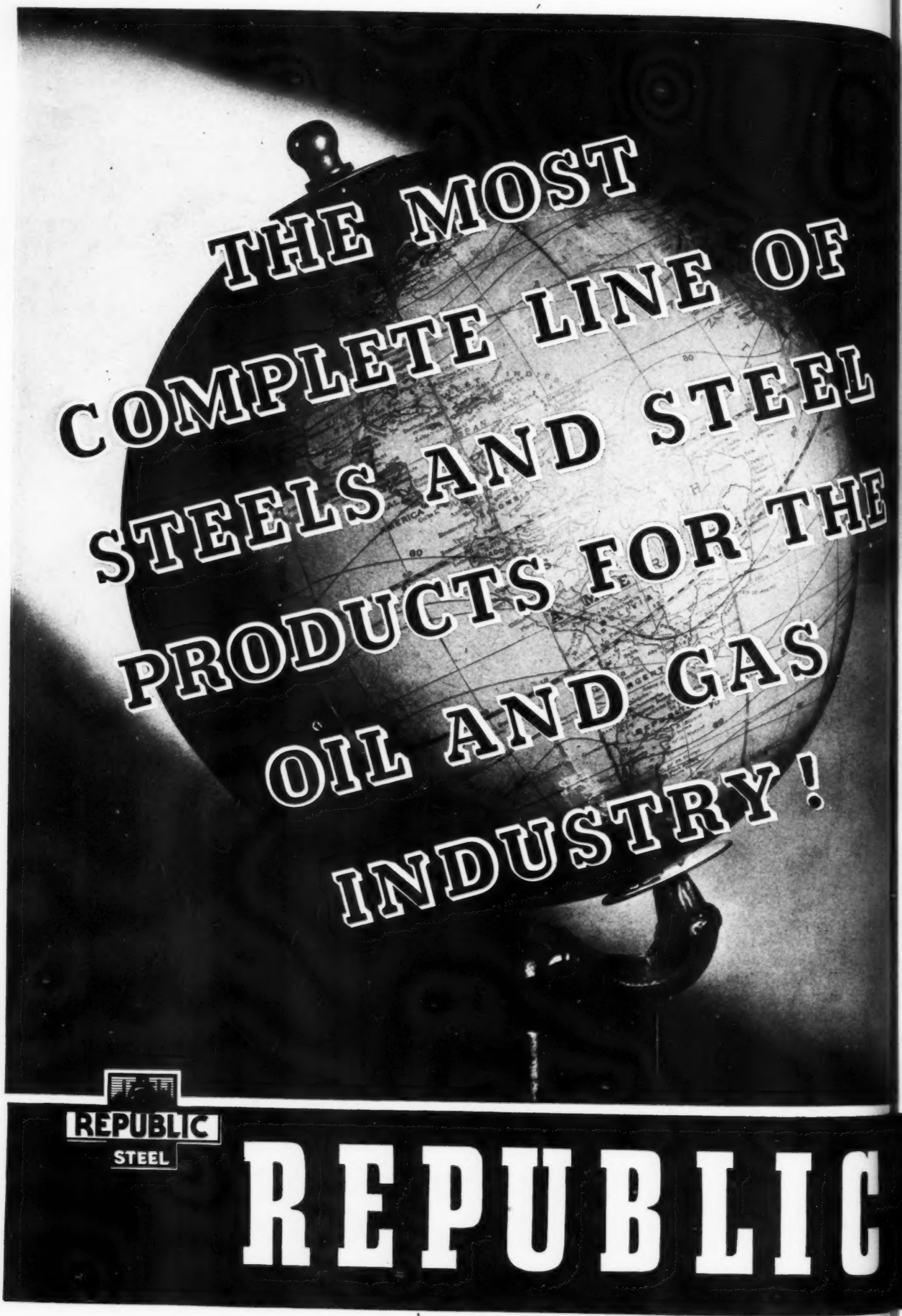
A great deal of dependence is being placed in electrical logging for correlation in developing fields, in augmenting data provided by physical cores, and in testing formations where no cores have been cut. An outstanding example of the value of the electrical log was that of disclosing the zone from which the Continental well at Wasco is producing. It was on the basis

(Continued on Page 48)

Right: Cores taken at depth below 12,000 feet

●

Below: Cores from 13,578 ft. to 13,593 feet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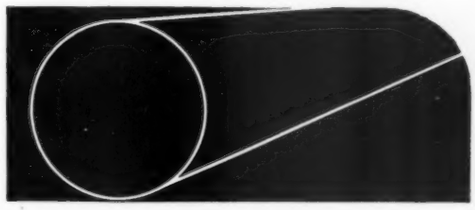

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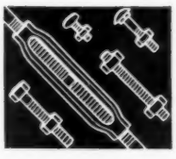

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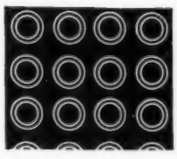

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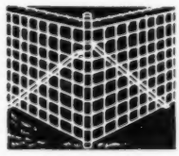

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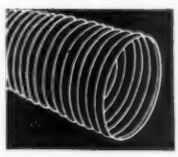

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(Continued from Page 45)

of the data provided by the electrical log that the liner was cemented above and below the producing sand and a lower sand not yet tested. Although oil showings were observed at the 13,100-ft. depth they did not seem very encouraging until the high porosity and high resistivity of the electrical log indicated the oil possibilities that were later proved.

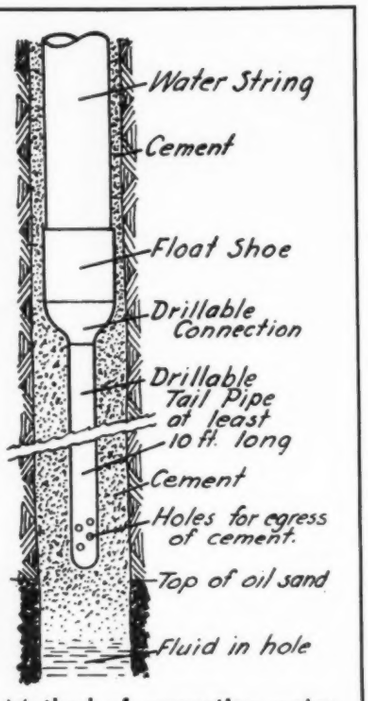
The adaptability of core barrels to any depth of drilling was proved by the 15,000-ft. well, which was cored at intervals to bottom, the last few hundred feet being cored continuously. From a depth of 9500 ft. onward, rock core bits were used, although the coring to 11,584 ft. was done with wire-line coring equipment. Wire-line coring using both soft and hard formation heads is being done extensively throughout the state and has facilitated coring operations where it has been adaptable.

Core analysis and paleontologic study of samples have been of great value in identifying strata, especially in the recently drilled deep fields in the San Joaquin Valley. Field study is made of all cores and those taken from a formation showing oil and gas are tested to determine porosity and saturation. Specific cores are usually selected for laboratory testing but those taken from any depth where formation characteristics may change receive paleontologic analysis.

Pressure Control

Provision of adequate protection against blow-outs is standard practice and a blow-out preventer of some type is generally put into service as soon as the surface string is cemented. Two cellar control gates are usually installed where emergency control may be needed but some of the companies are using a third gate as a master valve in several fields. When two gate valves are employed the upper is fitted with rams to close around the pipe and the lower for a complete shut-off.

The use of very heavy mud is not considered necessary but the conditioning of the mud is essential. In drilling wells to a depth of 11,000 ft., the 78-lb. mud produces at that depth a hydrostatic head of almost 6000 lb. per sq. inch. This is adequate to control the pressure and, if the mud is of the proper colloidality, to build up a thin but effective sheath on the wall of the hole as it is being drilled. This mud, however, must be constantly conditioned if any gas cutting is likely. The mere adding of weight material is not sufficient, as the weight of the 78-lb. mud is adequate as long as it remains effective. The work done in mud control and the protection afforded by this control have facilitated the drilling of deep zones with a combination of safety, speed, and good hole.



Method of cementing water string when hole is drilled through sand before running casing

Casing Programs

Formations naturally govern casing programs and the formations encountered in drilling the Rio Bravo field have permitted drilling 9,000 to 10,000 ft. of open hole. Here the surface string consisting of 11¾-in. or 13⅜-in. casing commonly is set and cemented at a depth of 2000 ft., although the 13⅜-in. casing recently run by one company was landed at a depth of approximately 2500 feet. These strings are floated-in; usually both a float shoe and a float collar one joint above the shoe are used.

The water string in this field is 6⅝ in. or 7 in. and is cemented just above the productive zone at a depth of about 11,220 ft., depending on the depth to the top of the sand. This casing is also floated-in on a float shoe and float collar, many of the shoes being the whirler type to aid in placement of the cement.

There are many fields in California in which the two-string program is suitable, and this program is used wherever possible. If the sand will hold-up, no liners are used. In many wells a drillable liner made of an aluminum alloy is set in the hole in order to provide for easy drilling-up without the necessity for removal or side-tracking if deepening or repair operations are later performed. The use of the drillable liner has increased to a considerable extent in fields throughout the state.

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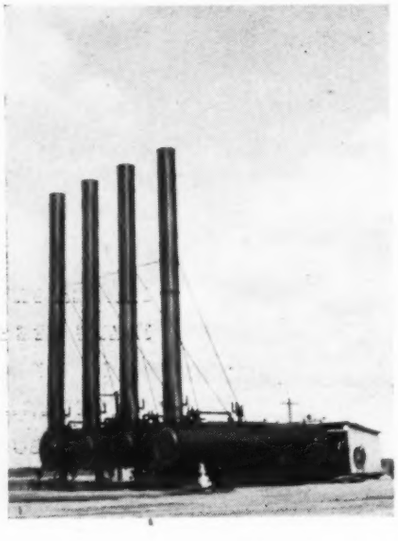

Cementing

When hole is drilled into or through the producing zone before the casing is run, the latest development for cementing the water string is to place the cement as a plug below the shoe and around the casing in one operation. This is done by means of a tail pipe or "stinger" attached to the shoe.

The necessity for this procedure is the requirement by the State Mining Bureau that when casing is cemented in a hole that has been drilled into the oil sand, a cement plug at least 10 ft. in thickness must be placed in the bore so that the shoe of the casing will be on or just above the plug. The reasons for drilling into or through the sand are to provide as large a hole as possible through the productive zone and, as in edge locations or in an unproved area, to be able to test the sand before the casing is cemented.

The cost of placing the plug in a separate operation is an additional expense; and although the casing may be lowered into the hole and then raised as the slurry starts from the shoe to form the necessary plug in shallow wells, it is not desirable to lower long strings of casing below the cementing point because of the hazard of freezing. If the well is rat-holed, of course,

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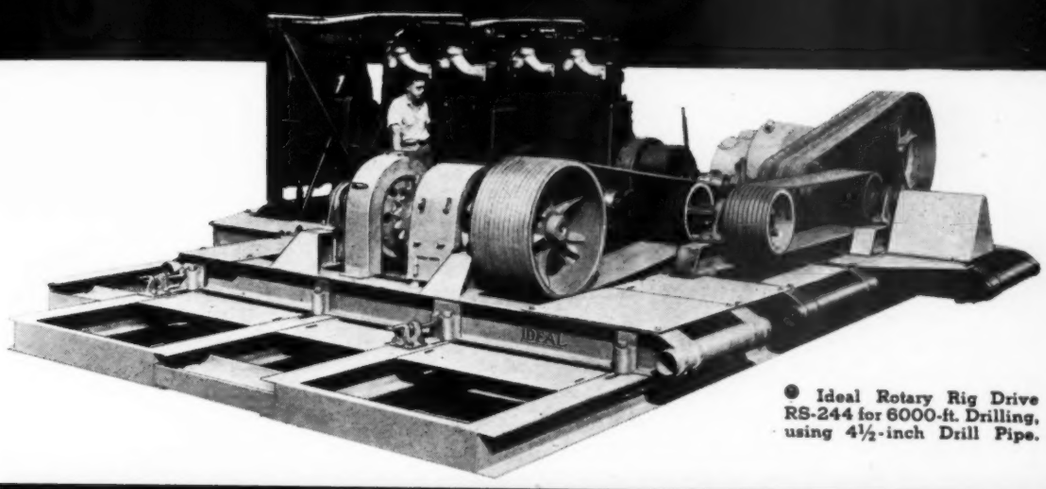

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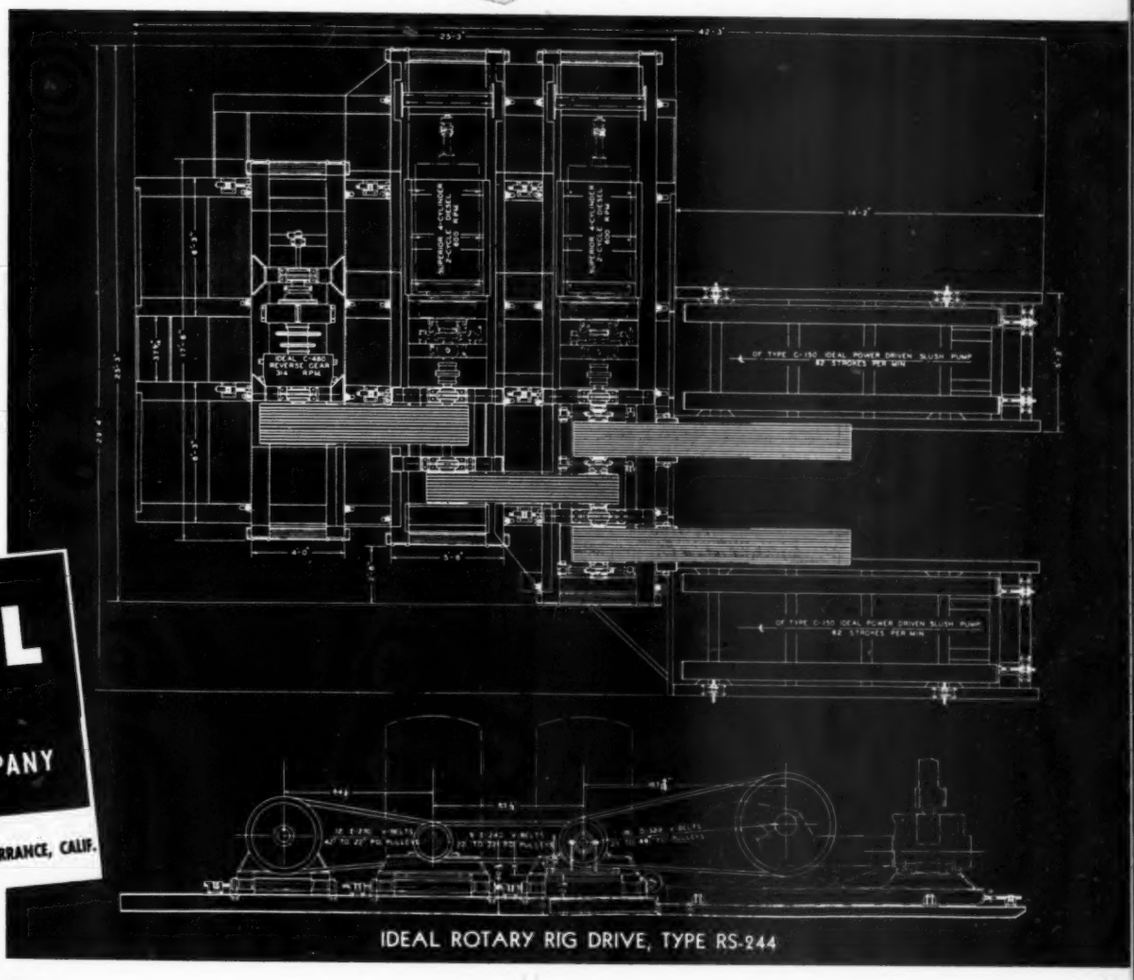

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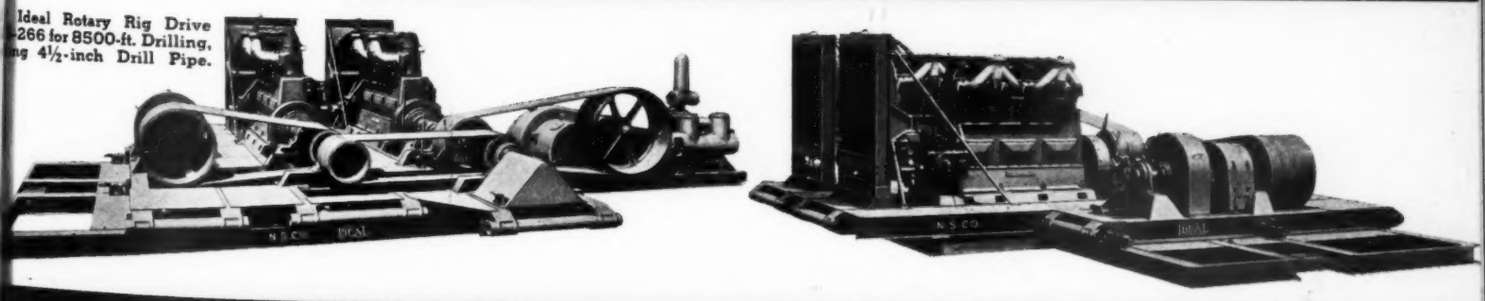


the casing cannot be lowered into the hole below the casing seat.

The procedure followed in using a tail pipe is illustrated in an accompanying sketch. A 3-in. drillable pipe 10 ft. or more in length is attached to the shoe. In the San Joaquin Valley the practice is to use a whirler float shoe having restricted ports and to pump the cement through the shoe ports and the holes at the bottom of the bull-plugged stinger or tail pipe. In the Los Angeles Basin, a float shoe is used and all the cement passes through the holes in the stinger. Whirler action can, however, be given to the cement by putting on the bottom of the tail pipe a shoe provided with whirler ports and pumping all the cement through these ports.

It has been found that the cement will settle only two or three feet below the bottom of the tail pipe during cementing. In making the water shut-off test the cement is drilled-out five ft. below the shoe, thus leaving at least five ft. of plug in the hole. The stinger, being made of drillable aluminum alloy, is readily drilled-out with the cement both when preparing for the water shut-off test and when cleaning the rest of the plug from the hole.

The behavior of cement under conditions found in oil wells has been studied by several of the major companies in California but the need for generally accepted standard specifications is recognized. In a paper[2] recently presented before the A.P.I., it was stated "That cement is an extremely important material to the industry is proven by the fact that we have been relying on it for many years to solve some of the most difficult problems encountered in the development of oil fields, those of excluding water." A standard for testing and grading cement has been suggested and the need for available information to aid in the selection and use of oil-well cement has been emphasized. It is hoped that beneficial results will follow.

Well Completion

Although the extensive use of gravel-packing in California probably started in the San Joaquin Valley during the last year, the Wilmington area has been the scene of most gravel-pack jobs during the last few months. The chief objects of gravel-packing have been to exclude sand and to support the wall of the hole. The general practice has been to scrape the wall of the hole to approximately 20-in. diameter and, after running-in the slotted or perforated liner, to fill the space around the liner with gravel.[3]

In the Wilmington field intervals of 700 ft. have now been gravel-packed. Some of the gravel first used exceeded ⅜ in. in size but it has been found that smaller gravel is better for excluding the formation sand in this field.[4] One company has used gravel passing through a ⅛-in. screen and retained on a 1/10-in. screen and the success achieved indicates that this is about the proper size.

Although not strictly a gravel-packing operation, one well in a coastal field was deepened and the open hole then filled with gravel without the use of a liner. The fluid was, of course, high enough above the gravel to fill the pump, which was set just above the gravel-packing. The gravel in the upper portion of the plug was larger than that used below to entrap the sand.

A similar application of gravel in a Wilmington well was made by dumping gravel in the liner of a well that sanded badly toward the bottom. The gravel was thought to have bridged at a point slightly above the bottom of the hole although there may have been more sand than was expected in the bottom of the hole. The gravel, however, has been effective in keeping sand from the pump and the oil evidently rises through the sand at the bottom and through the gravel, which entraps any sand accompanying the oil.

Many wells in the Wilmington field produce from three different zones, the Ranger, Upper Terminal, and Lower Terminal, and the oils from each of these are so different in character that many of the wells are completed to produce from each sand separately. The uppermost zone in the field is the Tar Zone, which is usually cased-off or produced with the Ranger. The casing and tubing programs employed to produce from each of the three sands separately in one well or from the Ranger and from one or both of the Terminal sands was recently described in detail at a meeting of the A.P.I. in Los Angeles.[6]

Briefly, the program for producing from two zones separately involves the use of an oil string, usually 8⅝-in., and tubing. The oil string is cemented just below the Ranger zone, and a string of tubing packed-off at approximately that point. Oil from the Ranger flows upward between the casing and tubing while oil from the Upper Terminal or both Terminal zones is produced through the tubing.

When three zones are produced separately, the oil string is cemented between the Ranger and the Upper Terminal and between the Upper and Lower Terminal. A flow string is run inside the oil string and set on a bevel seat at the bottom of the Ranger zone. The tubing is packed-off between the Upper and Lower Terminal zones. Oil from the Ranger flows upward between the oil string and the flow string; that from the Upper Terminal between the flow string and tubing; and that from the Lower Terminal through the tubing. A well thus completed functions as three separate wells and its Christmas tree has six flow lines.

In such completions casing has been cemented using special cementing collars and cement retainers, protection to the sands being provided by cementing baskets. One of the latest developments is the cementing-off of the intermediate formations by means of series cementing. Liner is made up with perforations opposite the three producing zones. The blank sections between perforations and above the upper perforations are cemented in three operations from the bottom upward. Five cement retainers are used, two of which function as casing bridge plugs. A cementing basket at the bottom of each blank section and an inverted basket at the top confine the cement to the space around the blank section of pipe. The metal parts of many of these cement retainers are made of aluminum alloy. After the retainers and the cement left in the pipe are drilled-out, production can be segregated by use of packers around the tubing.

The cementing of the liner in two stages in the Continental deep well at Wasco[6] was a particular operation to meet specific conditions but the operation demonstrated the value of special equipment for the purpose and proved the adaptability of modern cementing practice in performing cementing jobs at great depth and high temperature.

In the Torrance field at the present time wells are being completed by cementing blank pipe through the producing zone and then gun-perforating. In all other fields the gun perforator is more widely used in recompletion work and in plugging-back operations to bring-in production from zones previously cased-off.

[2] "Specifications For Oil Well Cement" by Eugene L. Davis. Paper presented at Spring Meeting, Pacific Coast District, A.P.I. Division of Production, Los Angeles, California, April 19, 1938.

[3] "Gravel-Packing Oil Wells." *The Petroleum Engineer*, December, 1937, and January, 1938.

[4] "Some Considerations in the Selection and Installation of Gravel Pack for Oil Wells," by C. J. Coberly and E. M. Wagner. Paper presented at the A.I.M.E. Meeting, Los Angeles, California, October 1, 1937.

[5] "Drilling and Production Problems of the Wilmington Field," by C. J. Dean. Paper presented at the Spring Meeting, Pacific Coast District, A.P.I. Division of Production, Los Angeles, California, April 19, 1938.

[6] "New World's Drilling and Producing Depth Records Established in California," *The Petroleum Engineer*, April, 1938.

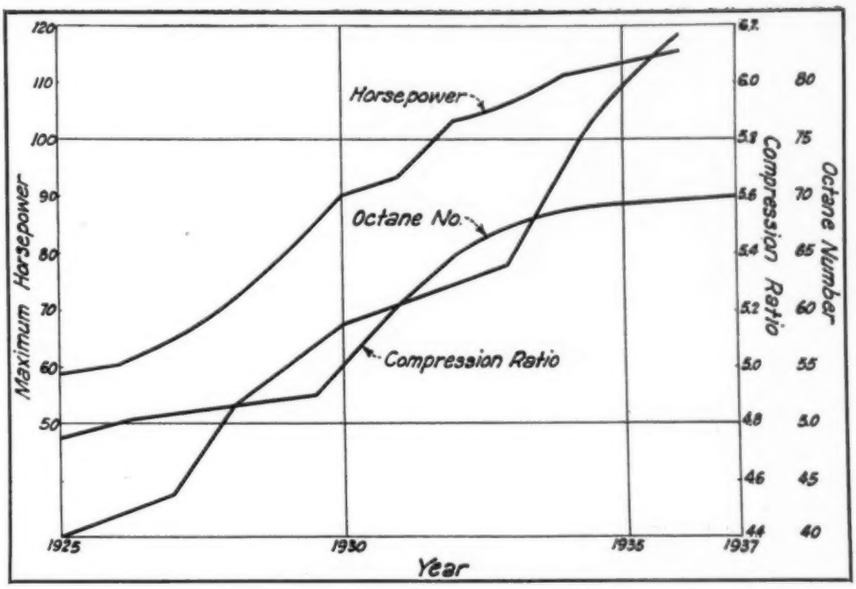


Fig. 1. Trend in octane number, and compression ratio and horsepower of automobile engines

Progress and Trends in the Refining Industry

By

A. W. TRUSTY

Chief Chemist, Arkansas Fuel Oil Company

THE refining industry is passing through another economic crisis. The present prices of refined products are low compared with the price of crude oil, and many refiners are finding it difficult to continue to operate. The petroleum industry has ceased its rapid growth, and has entered a stage of stable and highly competitive business. During such periods of economic and competitive strains the efficiency of operation is of major importance.

The last year has brought no new refining processes, but existing new processes have made rapid development. There is much obsolete equipment to be replaced and many processing and treating units of new type to be installed when economic conditions make it feasible.

The total crude capacity of refineries in the United States showed a substantial increase in 1937. The increase was the result of enlargement of existing refining facilities, not new plant construction, because the total number of plants operating decreased during this period.

Construction of new cracking units during the last year, mostly in the form of large combination units, was much greater than in 1936, and as a result the total for the United States increased some 155,000 bbl. to an all-time high of 2,327,215 barrels. In 1937 the output of cracked gasoline was higher than that of straight-run gasoline.

During the last year additional road tests have been made to correlate road performance and laboratory octane number determinations; road tests have been made to study the vapor-lock characteristics of the average automobile under service conditions; many polymerization units have been installed and much technical knowledge gained about the cracking reactions and characteristics of the poly gasoline; combination cracking units embodying the principle of selective cracking have become almost standard equipment in the modern refinery; solvent refining of lubricating oil has continued to increase, and much technical knowledge gained on the use of additives to increase the viscosity index and oiliness and to lower the pour point and corrosiveness; a report has been made on some fundamental investigations of the hydrocarbon constituents of petroleum; alloy metals have been further developed to meet the extreme temperature and pressure conditions of the modern cracking, reforming, or polymerization furnace; and new treating methods have been studied, much attention being given to tetra-ethyl lead susceptibility and inhibitor effectiveness on the treated product.

Octane Number of Gasolines

The average octane number of the regular gasoline in 1925 was 48; the average octane number in 1937 was 70. With the adoption of the L-3 method of octane number determination by a large number of refiners, and the consequent rise in octane number of regular gasoline, it appears that by the latter part of 1938 the average octane number of regular gasoline will be one or two numbers higher than at the same period one year before. The production of such a gasoline in the conventional cracking unit has reached the economical and practical peak; in order to stay in the octane race, it is necessary for the refiner to install auxiliary equipment such as reforming furnaces and polymerization units. Fig. 1 shows the trend in octane number, compression ratio, and horsepower of the automobile fuel and engine for the last 12 years.

The demand for high anti-knock fuel is greater for aviation than for automobile engines. Table 1 shows the trend during the last six years toward a higher octane fuel.

This table shows that the average octane number of aviation fuel (Air Corps) has increased in a six-year period from 70 to 92. It has been predicted that within three years 100-octane fuel containing less than 3.0 cc. of tetra-ethyl lead per gal. will be in general use by the military services. For commercial airline service, a similar 100-octane fuel will be used for take-off and 87-92-octane fuel containing little or no lead for cruising.

The airplane engine is designed to carry the maximum load with the minimum weight of engine, so efficiency of the motor is more important than in the automobile engine. Considerable work has been done to compare the efficiencies obtained when various fuels of high- and low-octane numbers are used. Klein showed that the permissible

TABLE I

Percent of Requirements of Air Corps for Gasolines of Various Octane Numbers

Octane Number	1930	1931	1932	1933	1934	1935	1936
58–65	56.4	31.6	16.6	6.5	5.3	3.9	3.5
87	43.6	68.4	83.4	50.2			
92				43.3	94.7	91.7	77.5
100						4.4	19.0
Average	70.6	77.7	82.2	87.3	90.2	91.3	92.6

increase in power was 12 to 30 percent, depending on engine type and operating conditions, when comparing 100-octane number fuel with 92-octane fuel. Modern engines have a 15 to 20 percent higher take-off rating when 100-octane fuel is used than when 87-octane fuel is used.

How is the refiner to manufacture such a large quantity of high anti-knock aviation fuel? One of the methods that is being used commercially today is the large-scale synthesis of iso-octane (2, 2, 4 trimethyl pentane). This synthesis involves the selective polymerization of the isobutylene in refinery vapors to di-isobutylene followed by hydrogenation of the polymer to yield the iso-octane. It is estimated that one-half billion gal. of iso-octane is potentially available in the United States. The iso-octane is blended with aviation gasoline stock of 70- to 75-octane number in such proportions that the finished stock containing 3.0 cc. of tetra-ethyl lead per gal. will be 100-octane number. Because of the combination of advantages inherent in iso-octane, namely, ability to "stand-up" best under the widest variety of engine operating conditions, high heat value, and good stability without the use of inhibitors, iso-octane is destined to remain one of the principal blending agents in the manufacture of high-octane number fuels.

Iso-pentane, manufactured from natural gasoline by sharp fractionation, is also added to the aviation fuel blends as a means of reducing the quantity of iso-octane required. Iso-pentane has a boiling point of 83 deg. fahr., an octane number of 90, and with 0.65 cc. of tetra-ethyl lead added is 100-octane number. The vapor pressure of 20 lb. at 100 deg. fahr. limits the amount of this hydrocarbon that can be added to the aviation blends.

Iso-propyl ether has great possibilities for the manufacture of high anti-knock fuel. A recent survey of potential supplies of propylene, the raw material for making iso-propyl ether, has shown that in this country sufficient supply is available, exclusive of all normal demands for other purposes, to produce at the present time approximately 340,000,000 gal. per year of technical iso-propyl ether. By blending approximately 40 percent of iso-propyl ether with a good grade of aviation gasoline, 850,000,000 gal. of 100-octane number motor fuel can be produced, which is more than sufficient to care for the demand. Iso-propyl ether has a blending value of about 105-octane number; by using tetra-ethyl lead and aviation gasoline, the resulting blend is 100-octane number.

Methods of Octane Number Determination

During the last year two methods of determining octane number of motor fuels have been used. Some refiners are using the Ethyl Corporation's modified method (L-3), and others are using the C.F.R. motor method. The use of two methods leads to confusion and a duplication of work, and it is the hope of all concerned that some more or less permanent method can soon be adopted.

The C.F.R. Committee is continuing road test work in the attempt to find a closer correlation between the test engine and the actual road performance of the motor fuel. In their 1937 report[1], this committee conclude that when a wide variety of fuels are tested, the C.F.R. motor method gives the best correlation; however, certain types of fuels are rated too high by the motor method and other fuels are rated too low. There is a need for a laboratory test method that will give a satisfactory evaluation of the relative knocking characteristics of all types of fuels. The differences between the two methods of octane number determination now being used are as follows:

Method	A. S. T. M. Motor	L-3 (Ethyl Corp.)
Spark advance (at 5:1 comp. ratio)	26	16
Mixture temperature	300 deg. fahr.	260 deg. fahr.

Straight-run fuels show practically the same rating by both methods; cracked gasolines ordinarily show 0.5- to 4-octane number differences depending on the extent to which the gasoline was cracked in its manufacture.

Doctor Sweetening

The sweetening of gasoline with doctor solution and sulphur is one of the oldest and most widely used refining processes. The complete reactions taking place during the various phases of the treatment have never been fully understood. The refiner is beginning to appreciate more and more the variables and side-reactions, because recent experimental work is showing the effect of these variables on such tangible things as tetra-ethyl lead susceptibility, inhibitor effectiveness, color stability, and octane number.

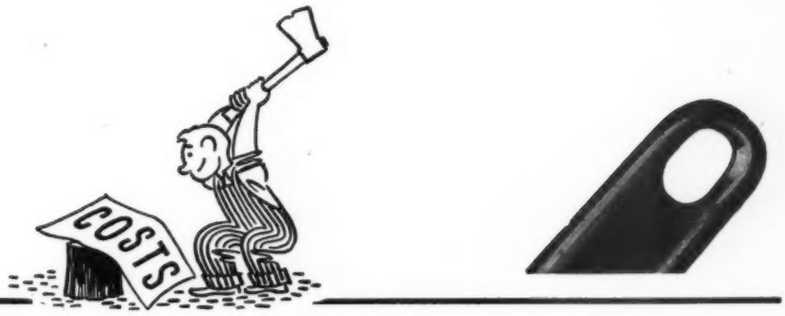
At the Dallas meeting of the American Chemical Society in April of this year, Lowry, Dryer, et al., presented an excellent paper pointing out the effect of the variables in doctor sweetening and their influence on inhibitor effectiveness in the sweetened gasoline.

Most refiners assume that if their doctor-sweetened gasoline is non-corrosive, the small quantity of sulphur present in excess of the amount actually required to complete the sweetening reaction is of no particular importance. That this assumption is fallacious is becoming evident. The following table shows the effect of excess sulphur in a sour West Texas gasoline. In these treats, the sulphur required to break was added to the gasoline before contact with the doctor solution. None of these gasolines was corrosive to the copper strip by the A.S.T.M. method:

Excess sulphur, percent	0	.005	.0075	.010	.015
Induction period, min.	200	210	115	125	100
.013% U. O. P. Inhibitor No. 4	380	400	285	210	175
Copper dish gum, mg./100 cc.	299	273	327	389	357
.013% U. O. P. Inhibitor No. 4	5	6	74	82	138

Elementary sulphur added to a sweetened gasoline has no marked effect on the effectiveness of an inhibitor and even a small addition of excess sulphur produces a corrosive product. In fact, about .005 percent elementary sulphur added after doctor treatment will make a corrosive gasoline. Polysulphides formed during the sweetening reaction are non-corrosive to the copper strip, but appear in the usual tests for elementary sulphur. Either elementary sulphur or the poly-

[1]Boyd, *Oil and Gas Journal*, December 2, 1937, p. 44.



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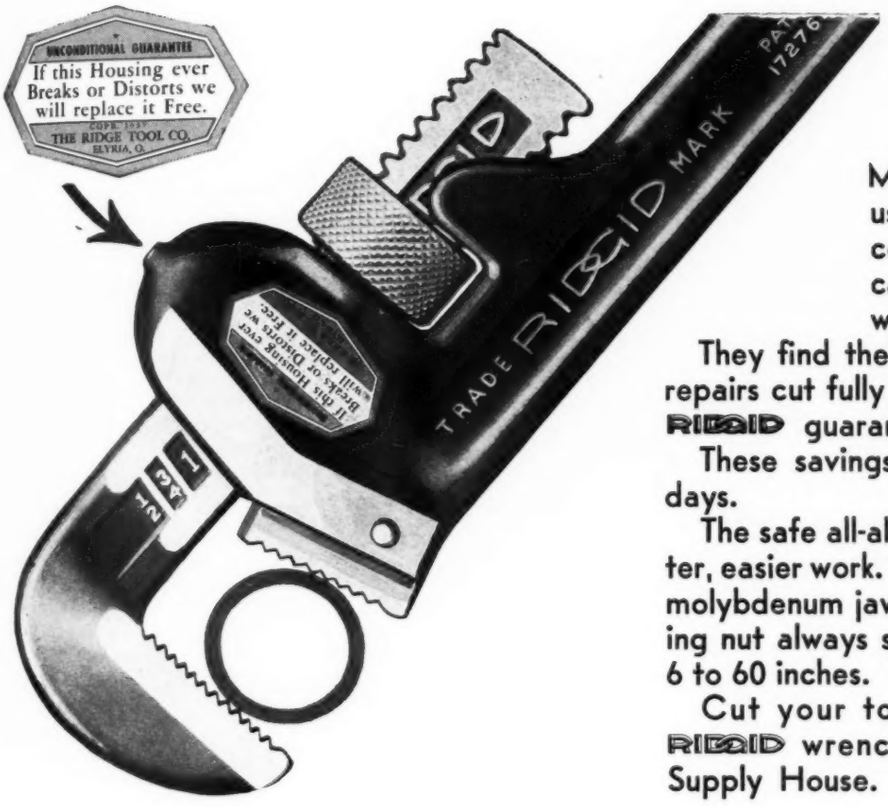
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TABLE 2

Effect of Sulphur on Lead Requirements

(Adding 1 percent sulphur as the following compounds)

	cc. lead to blend to 70.5 octane
Original gasoline (64.4 octane)	.54
Gasoline plus ethyl mercaptan	1.33
Gasoline plus diethyl sulphide	.83
Gasoline plus ethyl sulphide	1.40
Gasoline plus ethyl polysulphide (Et_2S_3)	1.79

sulphides will react with the mercaptides to complete the sweetening reaction. The excess sulphur shown in the table is probably polysulphides and not elementary sulphur. It appears then that the polysulphides are the compounds that affect inhibitor susceptibility. One practical application of this work is that the sulphur should not be added to the sour gasoline before or during the contact of the doctor solution, but preferably should be added after the actual doctor contact; the polysulphides already present are used in the sweetening reaction, and elementary sulphur added to complete the break; by this procedure, the polysulphides are removed, and the possibility of inhibiting gum formation in the treated gasoline is the greatest.

Work done by Buell and Schultze, and by Birch and Stanfield[2] shows that the sulphur compounds, especially the mercaptans and sulphides, have a marked effect on the tetra-ethyl lead requirements.

Thus it is important to remove the mercaptans, or as many as can be removed economically, by using caustic soda washes before doctor treatment, and during doctor treatment to avoid leaving any amount of polysulphides in solution.

Plumbate Treating

A report was given recently by S. C. Smith, Paluxy Asphalt Company, on the use of sodium orthoplumbate for oxidizing mercaptans in sour gasoline. A 300-amp. motor generator supplies the direct current. The cell box, made of iron, copper, lead, or some other suitable metal, is the anode. Multiple cathode plates are enclosed in porous clay jars. The plumbite solution is circulated through the cell box until the correct conversion to plumbate has been effected. The plumbate solution is then mixed with the caustic-washed sour gasoline to oxidize the mercaptans to the disulphide type of sulphur compound. The hydrogen evolved at the cathodes is the only loss. An East Texas cracked gasoline required a consumption of 0.024 kw-hr. per bbl., and a Smackover cracked gasoline 0.071 kw-hr. per bbl. to treat satisfactorily.

[2]Birch, *Ind. Eng. Chem.* 28, 668, (1936).

Vapor Lock Road Tests

In 1937 a series of road tests sponsored jointly by the Western Petroleum Refiners Association and the Natural Gasoline Association of America was made to investigate the performance of the fuel systems of representative 1937 model automobiles. Nine different makes of cars were driven 10,000 miles over a designated road near Pawhuska, Oklahoma.

The results of these road tests showed that at an atmospheric temperature of 100 deg. fahr. car A could operate satisfactorily on a gasoline having a Reid vapor pressure of 9.04 lb., whereas car E would vapor lock if the vapor pressure of its fuel exceeded 6.8 pounds. This means that the refiner must blend his gasoline so that it will operate satisfactorily in the poorest car from the vapor lock viewpoint. The permissible butane content of the fuel for car E is 0.95 percent, whereas as much as 3.6 percent butane can be blended in the fuel for car A. The economic aspect of this difference in permissible butane content in respect to octane number of the gasoline, tetra-ethyl lead requirements, gas loss at the refinery, etc., is apparent to the refiner.

This vapor lock road data also showed that the vapor loss from the rear tank and carburetor vent will amount to four to seven percent or even more in hot weather, depending on the driving conditions. A conservative estimate of 1.96 percent annual loss of gasoline was made. The loss of the lightest fractions of the fuel results in an octane loss of one to two octane numbers and will average 0.54-octane on an annual basis. The annual loss to the motorist is $65,000,000.

This splendid work points out the need for closer coöperation between the refining and automotive industries. Road work of this nature brings the facts to the surface, and when all the facts are known, it will be easier for the makers of the engine and of the fuel to understand each others' problems.

Salt in Crude Oils

The refiner in the Mid-Continent area is becoming salt conscious. Some salt is appearing in the crude oil produced in the northern, western, and southern part of the East Texas field; also, small amounts of salt are found in other parts of this field. The number of wells being acidized in other fields is increasing, and in some of the production from these wells, the salt has been giving the refiner trouble by causing corrosion and deposition.

Heat and pressure with a water wash is the most common method of desalting. As most of the salt is present in the crystalline or dehydrated form, and in some oils is held enclosed in a particle of paraffin wax, it is necessary to add water to dissolve and remove the salt. In desalting East Texas crude, it has been found that if three to five percent water is added to the oil to dissolve the salt, the resultant brine settles best at a temperature of about 225 deg. fahr. at a pressure of at least 110 lb. on the settling drum; and the capacity of the settling drum must be sufficient to allow 50 minutes for the settling process in continuous operation. Such a system usually will reduce the salt content below five lb. per 1000 bbl. of oil. Loss of light fractions can be prevented either by maintaining pressure on the drum or by equipping it with a vaporizing dome connected with a vapor line or fractionating tower. It is important to carry sufficient pressure to avoid boiling of the oil; boiling causes a turbulence that reduces the rapidity of settling.

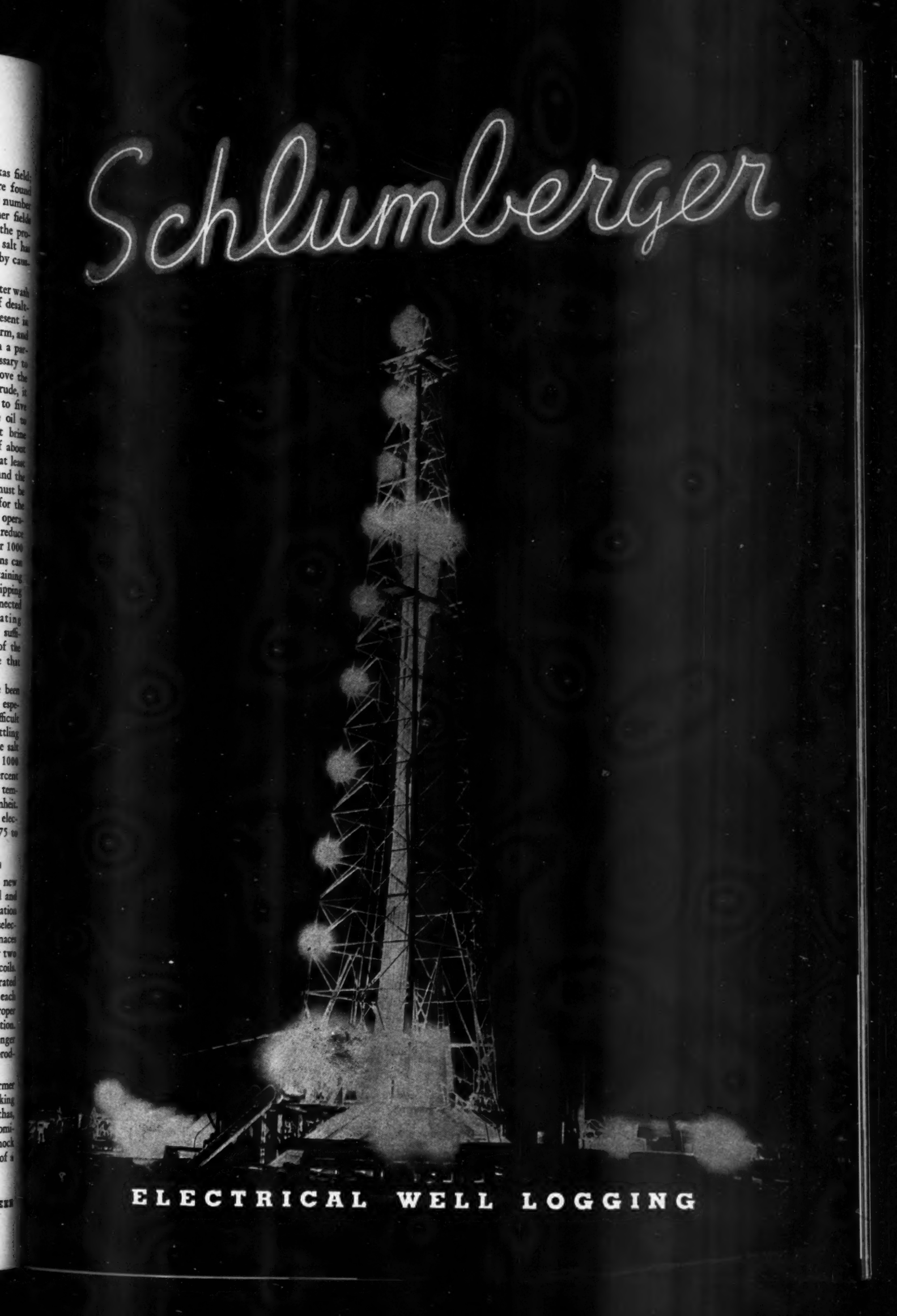
Electrical desalting units have been found to treat oils satisfactorily, especially heavy crudes, which are difficult to desalt by the heating and settling method. Typical units reduce the salt content from 150 lb. to 5 lb. per 1000 bbl. of crude oil. About 15 percent water is used and the operating temperature is about 180 deg. fahrenheit. The overall treating cost by the electrical process is reported to be 0.75 to 1.1 cents per barrel.

Cracking and Polymerization

During the last year several new cracking units have been installed and nearly every one was a combination unit embodying the principle of selective cracking. Two or three furnaces are used, and in some units, one or two furnaces have two sets of heating coils. The cracking stock is thus separated into three to five fractions and each fraction is cracked under the proper temperature-time-pressure condition. Such selective cracking will give longer runs and higher yields of liquid products.

Flexibility demands that a reformer unit be a part of the new cracking unit in order that low-octane naphthas, which cannot be ethylized economically, can be converted into anti-knock motor fuels. Fig. 2 is a flow sheet of a typical modern combination unit.

Schlumberger



ELECTRICAL WELL LOGGING

The polymerization process is one of the most important developments of the petroleum refining industry. More than 9,000,000,000 gal. of polymer gasoline can be produced yearly from hydrocarbon gases produced in the United States, of which over 1,000,000,000 gal. may be iso-octane fuel of 95- to 100-octane rating. When it is considered that most of the hydrocarbons used as feed stock to the poly unit are hydrocarbons that would have been used as fuel gas, the far-reaching effect of the polymerization process from an economic viewpoint can be seen. The principal economic goal of this process was the conversion of partially waste gases into motor fuel; the objective was not only attained but the product has many inherent advantages as a blending agent in the manufacture of high-octane motor fuels.

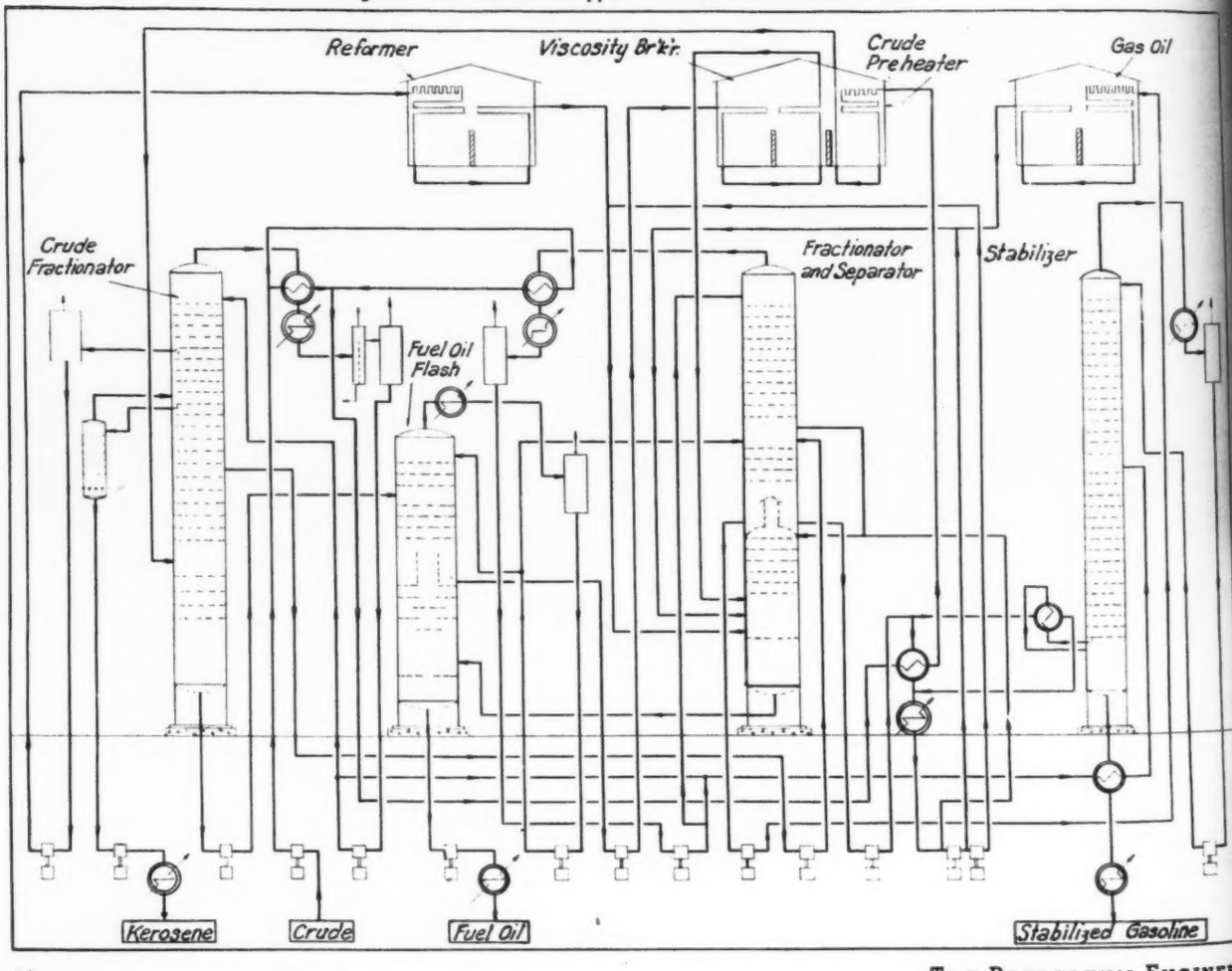
Chemical Constitution of Petroleum

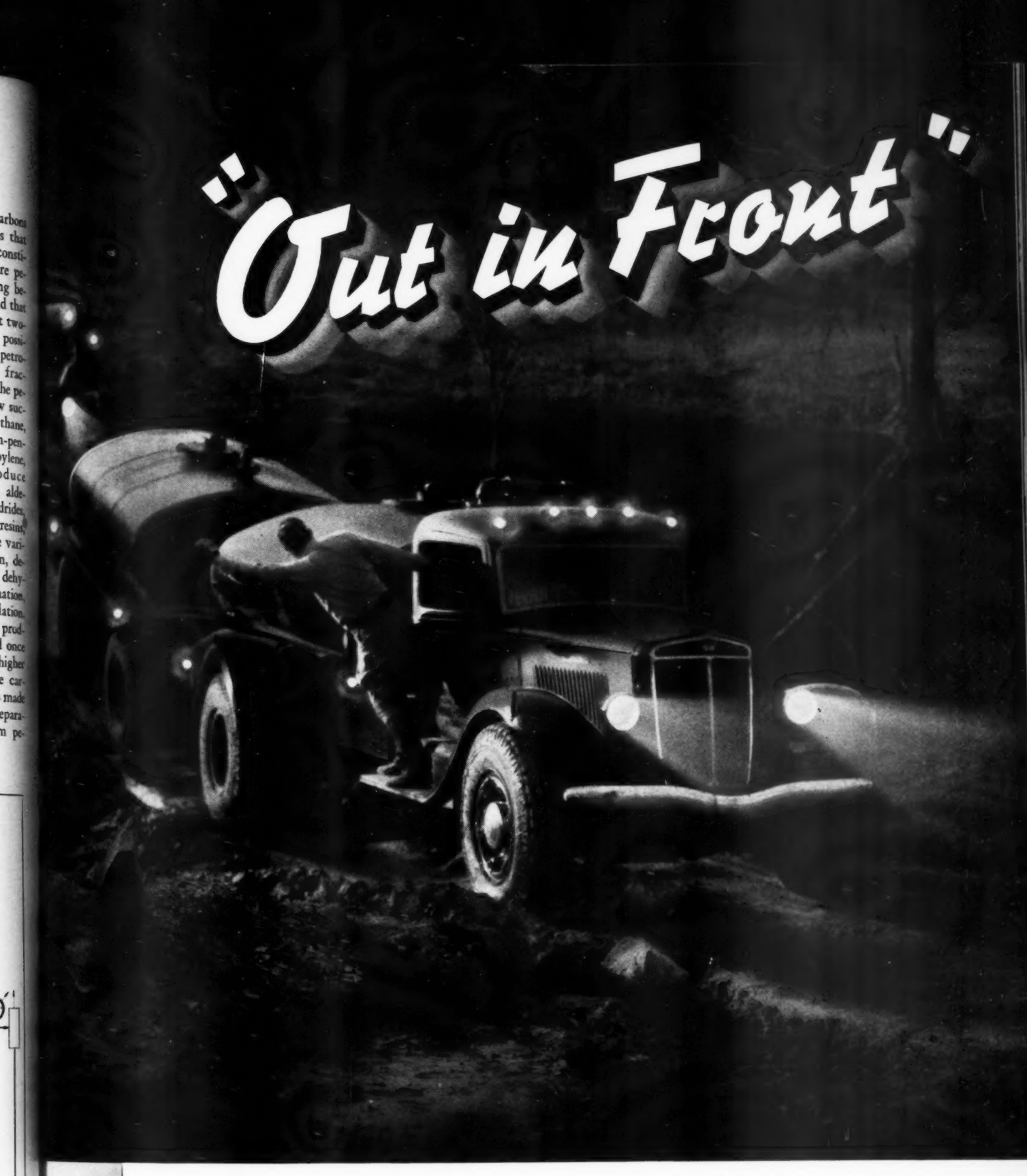
There was completed last year a decade of work on the chemical constitution of petroleum under the program begun jointly in 1927 by the American Petroleum Institute and the National Bureau of Standards, and performed in the laboratories of the National Bureau of Standards at Washington. This work has done much to enlarge the knowledge of the chemistry of petroleum fractions.

Since the beginning of research on the chemical constitution of petroleum many decades ago, one of the most interesting but perplexing questions has been: "How many hydrocarbons are there in petroleum?" It is likely that this question can never be answered literally; but, from the work that has so far been done, a partial answer may now be given with respect to a large part of the gasoline fraction of Mid-Continent petroleum. Most of the investigations have been performed on gasoline fractions because of the small number of hydrocarbons present in the light fractions as compared with the heavier fractions. For example, the hydrocarbons in the lubricating oil fractions contain, on the average, about four or five times as many atoms per molecule as those in the gasoline fraction; the number of possible isomers of triacontane, $C_{30}H_{62}$, exceeds 4,000,000,000, whereas for octane, C_8H_{18}, the number is only 18.

The hydrocarbons in Mid-Continent straight-run gasoline are present in the proportion, paraffins 60 percent, naphthenes 30 percent, and aromatics 10 percent. No unsaturated hydrocarbons are present. This work indicates that eight individual hydrocarbons constitute about one-half of the entire petroleum fraction normally boiling between 131 and 293 deg. fahr., and that 18 hydrocarbons constitute about two-thirds of this same fraction. The possibility of manufacturing pure petroleum hydrocarbons by efficient fractionation methods can be seen. The petroleum chemical industry is now successfully utilizing methane, ethane, propane, n-butane, iso-butane, n-pentane, iso-pentane, ethylene, propylene, n-butene, and iso-butene to produce alcohols, glycols, ethers, oxides, aldehydes, ketones, esters, acids, anhydrides, chlorinated compounds, amines, resins, and iso-octane motor fuel by the various processes of polymerization, depolymerization, hydrogenation, dehydrogenation, oxidation, halogenation, hydration, dehydration, and alkylation. It is apparent that the range of products can be enormously increased once the use of hydrocarbons of higher molecular weight (six and more carbon atoms) as starting material is made commercially possible by the separation of such hydrocarbons from petroleum.

Fig. 2. Flow sheet of typical modern combination unit





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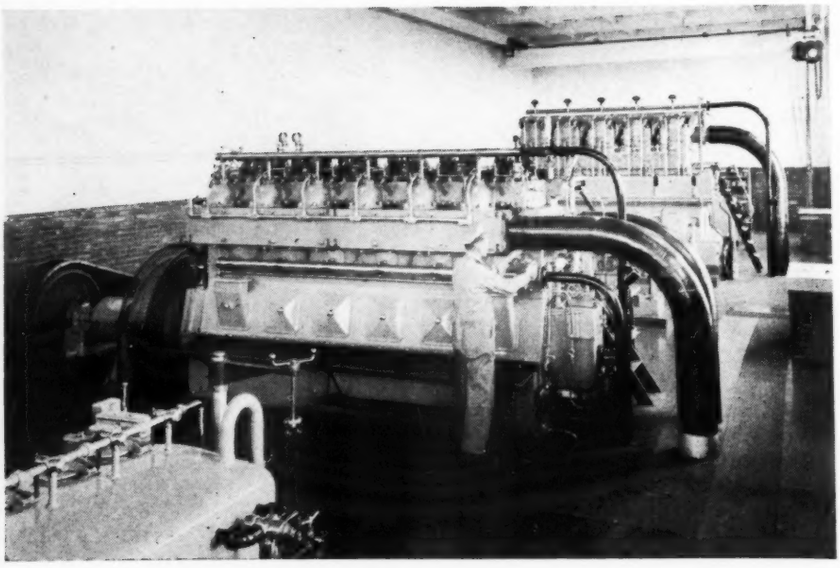


Diesel engines used in gasoline pipe line station

The Operation and Maintenance

By FRANK H. LOVE

PIPE lines for transporting gasoline or other finished products do not differ greatly from crude oil pipe lines. The gasoline line, being a development of a relatively modern era, naturally includes innovations and improvements in design and construction that do not exist in the pioneer oil pipe lines. It should be of interest to review the problems that developed after the idea of constructing a gasoline pipe line was conceived. Naturally the executives and engineers sought a solution among the empirical observations made by the builders of oil pipe lines.

Briefly, the new problems for which there was no ready-made answer included, (1) the spacing of stations, not overlooking the fact that the liquid velocity should remain practically constant at maximum capacity through comparatively long sections in order to obtain maximum efficiency; (2) the type of pumping equipment; (3) the effect of viscosity, gravity, and temperature on pressure and capacity; (4) the maximum main line and branch line diameter that could be economically used when considered from a line load factor standpoint; (5) the determining criteria when moving tenders of different characteristics; (6) a satisfactory, economical, and expeditious method of increasing line capacity to meet increasing load; and, (7) the type of construction capable of withstanding the operating pressures involved, considering the value of the product being transported.

The first stations, consisting of Diesel engines driving reciprocating pumps, known as main line primaries, were situated as closely as possible to the point, indicated by the hydraulic computations, on the pressure gradient line of the actual pipe line profile to produce maximum efficiency. The formulae used in the computations, although wholly irrational because of certain contradictory phenomena, have proved quite acceptable from an engineering standpoint and it can be stated reliably that the errors involved are negligible. After several years of operating experience it can be truly said that locations selected in this manner have proved wholly satisfactory even if some of the sites when chosen were nearly inaccessible. The type of pumping equipment closely resembled in design the equipment installed in the newer crude oil pipe line pumping stations, differing only in the increased depth of the pump stuffing box, the facilities installed to lubricate the plungers, and the arrangements made to introduce low-pressure air into the pump suction alleviators to compensate for that lost by reason of gasoline absorption. The solid steel ball valves were found to be too sluggish for the rapid transition of liquids having specific gravities as low as 0.66, consequently a light micarta-faced brass valve was adopted as standard.

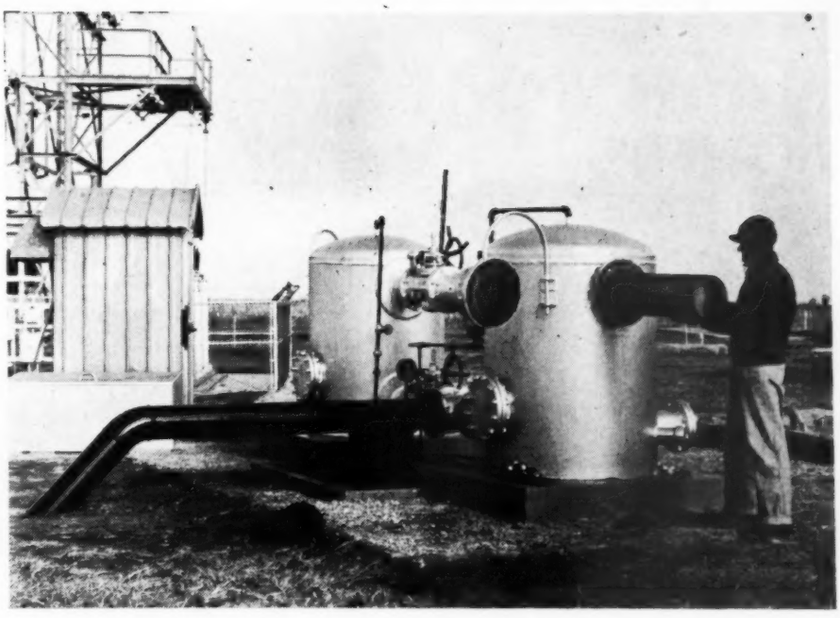
The effect of gravity, temperature, and viscosity on line pressure and capacity was thought to be of minor importance; however, careful observations made over a period of years indicate that these factors are of paramount importance although less significant than when crude oil is the material transported. It is expected in the near future to correlate the data being accumulated and to produce a dependable gasoline pipe line formula that can be applied to satisfy all working conditions.

The line of demarcation that limits the pipe diameters can be clearly ascertained when considering the tangible load factor, and it is evident that this load factor should always have a value sufficiently high to permit the receipt of segregated products as complete entities. A maximum diameter of 8 in. for main lines and 4 in. or 6 in. for branch lines has been generally accepted as economically sound. The 8-in. diameter main lines are of particular interest, requiring as they do an approximate line fill of 328 bbl. per mile, which necessarily is dead storage so far as the pipe line company is concerned. Comparing the line fill required for 10-in. pipe, we find a dead storage increase of 56 percent, reflecting an intangible financial investment in storage capacity commensurate with that increase. This is only one of the contributing factors that govern the line size, however, and financially it does not compare in magnitude with the cost of steel, right-of-way, damage, and other factors that combine to determine the final expenditure.

Gasoline tenders of varying physical and chemical characteristics must be pumped without interruption if homogeneity of the product is to be expected at the destination. When the hydraulic traverse of the line is considered, it is found, of course, that the liquid velocity is greatest at a point slightly below the pipe's axis. The interspersion of a product of one grade with that of another does not occur so long as the liquids remain in motion by reason of pump-generated energy, however.

Consideration naturally must be given to possible increases in capacity when designing lines of definite length that operate at maximum pressure. If all conditions are favorable it is customary to install boosters to increase

Charging tank-type strainers



the line capacity as much as 50 percent, at the same time remaining within the limits of economic balance. For capacity increase exceeding 50 percent, it is advisable to lay new lines paralleling those originally laid rather than to construct strategically situated loops. Because the roughness factor of pipe lines of equal diameter varies, the velocity through adjacent loops is not equal, i.e., the line having the highest roughness factor always carries more than its quota of the volume composing the tender; consequently, the construction of line loops to reduce pressure or increase capacity may result in the blending of liquids that were originally shipped as segregated products.

# of Gasoline Pipe Lines

It is therefore logical to conclude that to increase capacities only two acceptable methods are available, namely, the installation of boosters or the laying of a parallel pipe line that necessarily should operate as an independent unit. The economic value of the finished product, the high operating pressures of 850 lb. to 875 lb. per sq. in., and the fire hazard involved if a line break should occur demand that pipe and fittings of ample strength should be used in the fabrication of manifolds, lines, and connections. The massive structural design of pipe and connections, in addition to the special metallurgical trim used in valve design, which, for example, includes stainless steel seats, disc, and stem, combine to increase the construction cost considerably.

A finished product line operates similarly to its more mature relative, the crude oil pipe line, and the several departments that are coördinated to constitute a successful operating personnel might be briefly enumerated as (1) pumping station crews, (2) dispatchers, (3) chemical testers, (4) mechanics, (5) line maintenance gangs, (6) telephone men, (7) men on special assignments, and (8) superintendents.

The one outstanding problem that has confronted the operating departments of the several carriers, and has assumed momentous importance, is the maintaining of the maximum throughput for which the line is designed. The equipment developed to clean and trap the sediment and water that inevitably settle in the low parts of the line is the result of an analysis and study of irregular conditions. The knowledge available and the empirical data accumulated pertinent to line cleaning were practically worthless where finished products were concerned when reduced capacity caused by accumulation of water and sediment first came into prominence. The type of line scraper was unsuitable, the scraper trap by-pass lines were too small, and the strainers were practically worthless. Many amusing and instructive experiences are listed in the records concerning the difficulties encountered, one of which recommended water movements as the only safe and acceptable method of eliminating the obstructions. The introduction of a scraper of new design, however, facilitated cleaning of the line and this was particularly noticeable when the throughput capacity, reduced by reason of water pumping, became a line balance factor. Certain changes in product specification made possible the development of large capacity strainers. In the design the arrangement previously accepted as standard for this type of equipment was ignored. The old types necessarily included fine screen mesh baskets encased in chambers that had no appreciable effect on the stream velocity and the foreign matter in suspension in the liquid was removed only by the screening baffle.

Inserting scraper to clean gasoline pipe line

The tank-type strainer now in use was developed because of the unsatisfactory behavior of the strainers initially installed. It is essentially a water and sediment trap consisting of two compartments. The lower inlet compartment reduces the stream velocity 64 times below normal and permits precipitation of water and large sediment particles, and the upper compartment, which is filled with loosely-packed excelsior, is capable of successfully extracting foreign matter of 200 mesh fineness. Sensitive indicating and

(Continued on Page 64)

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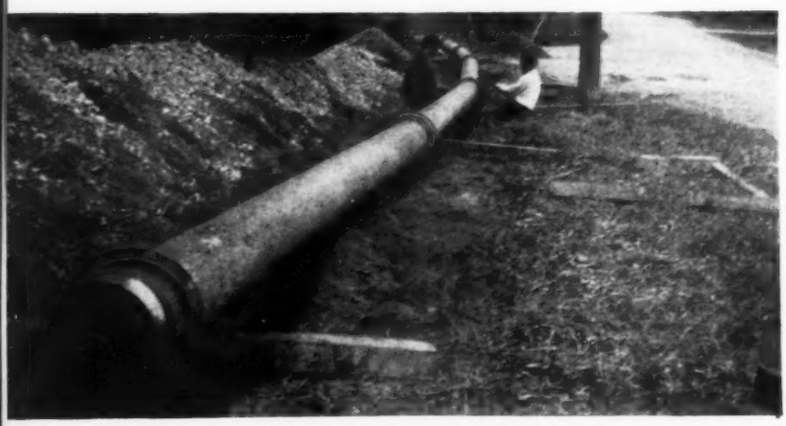

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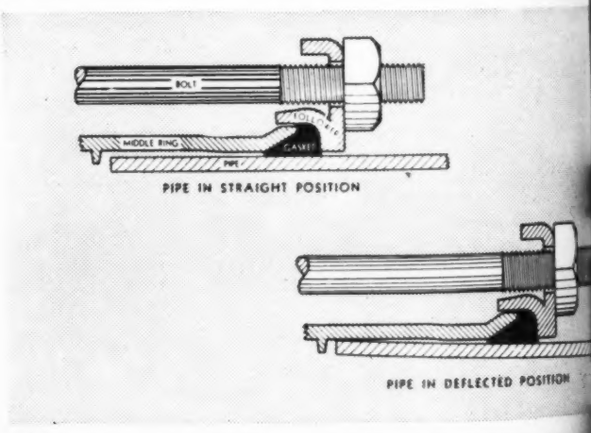

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and "follow" both lateral and in-and-out pipe movements, yet main
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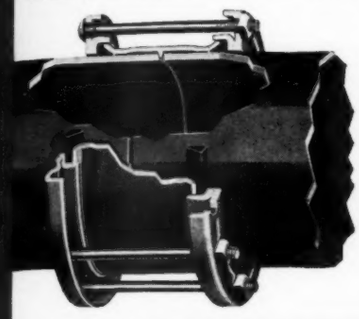
FLEXIBLE!*

(Cutaway view of Dresser Coupling, Style 38)



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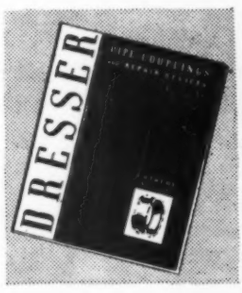


For further details, write for our General Catalog No. 36, a virtual handbook on pipe joints. ●S. R. DRESSER MFG. CO., BRADFORD, PA. *New York:* 17 East 42nd Street; *Chicago:* Peoples Gas Building; *Houston:* Shell Building; *San Francisco:* 1038 Polk Street; *In Canada:* Dresser Mfg. Co., Ltd., 60 Front Street, West, Toronto, Ontario.

DRESSER
PIPE COUPLINGS

(Continued from Page 61)

recording pressure gauges connected to the inlet and outlet of the strainer reveal the pressure differential and inform the operator when this differential exceeds that recommended for successful operation.

Line capacity reductions as great as 13 percent and the promiscuous consumption of booster station electric power, which incidentally was not converted to useful work, necessitated installation of tank-type strainers and their attendant sump and separator systems at primary and booster stations in order to provide adequate facilities for the trapping of foreign matter expelled from the lines by scrapers. The average distance between the transmitting and receiving scraper traps is 25 miles and scrapers of the rubber disc type are run in batteries of six, eight, and even 12 per section at intervals of 30 minutes. The rubber discs, which are the scraping agents, are not impervious to gasoline; in fact, the reaction is such that the expansion of the rubber compensates for the disc perimeter wear within the 25-mile section that each scraper traverses and scrapers usually arrive at their destination fitting the pipe so snugly that double sheave rope blocks are necessary to pull them from the scraper barrel. The total number of scrapers required to clean a section thoroughly depends upon the line topography, the weight of the sediment to be removed, and the water trapped in the depressions. No experiments relative to the pressure differential existing between the ends of a scraper have been performed but it is logical to assume that the sediment-carrying capacity of a scraper in total weight as approximately equal to the pressure drop across the scraper calculated as an actuating force. There are several intangible factors involved, however; the most important are the friction coefficient of the sediment and its coarseness.

Scrapers are transmitted and received at primary or electric stations as necessity demands, and this work constitutes part of the daily operating routine whenever the line capacity drops below normal or the pressure increases above the operating limit.

The line-cleaning facilities installed at electric booster stations have been very effective, particularly when one considers that float tankage is not available at these points. Sediment loads totaling several tons have been received at electric booster stations and effectively separated from the liquid by tank-type strainers in periods of time not exceeding four hours. The efficiency of these strainers should be obvious to the operators of centrifugal pumping equipment, especially when it is considered that normal speed of operation of the pump is 3560 r.p.m. despite the fact that sediment and abrasive material in amounts many times that which would freeze the rotating element are being precipitated from the pump suction stream by the tank-type strainers. In passing from this phase of operation it is interesting to note that the centrifugal pump suction pressure averages 10 lb. per sq. in., equivalent to a tank head of 31.6 ft. of gasoline, and the electric power consumption necessary to prevent freezing of the water legs of these strainers in frigid atmospheres averages 800 watts.

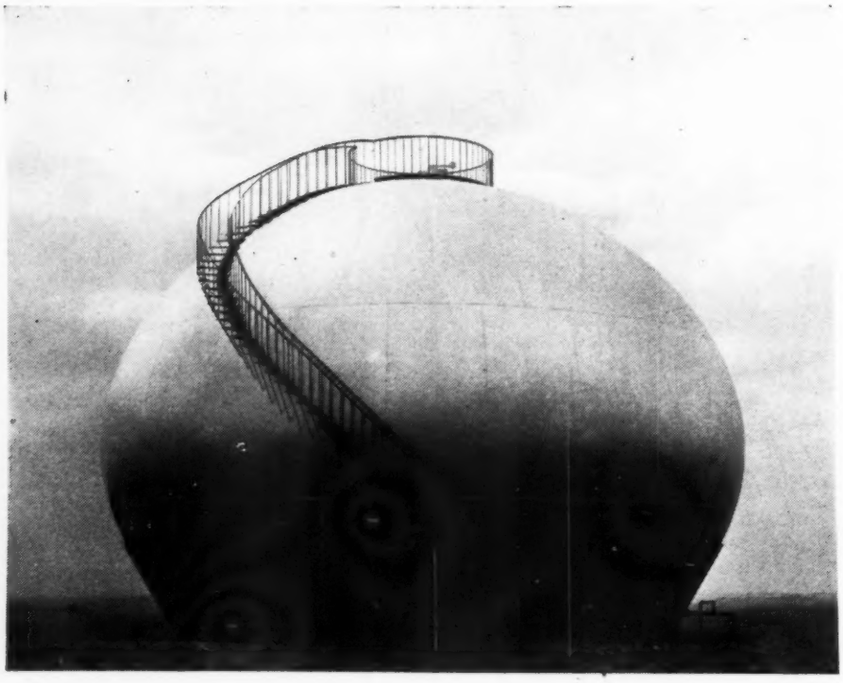
The numerous problems that develop from time to time to impede operation would provide material for a lengthy discussion. In general, the principal difficulty that confronted operators in the early days of gasoline pipe lines pertained to packing for reciprocating pumps. After considerable research a suitable packing for reciprocating and centrifugal pumps eventually resulted. It is now not uncommon to operate centrifugal pumps with a maximum leakage at the packing glands of one drop each minute; most reciprocating pumps operating at 45 r.p.m. do not leak and many do not require lubrication.

The anathema of all gasoline pump packing is abrasives and water, and their elimination is dependent upon the efficiency of straining equipment, consequently one cannot reiterate too often the necessity for using strainers that will eliminate deleterious material.

To follow the progress of a tender of finished products from its origin to destination may prove interesting and informative. Temperature and gravity determinations are made before the actual pumping begins, a prepared colored liquid marker known as a "flag" is introduced immediately ahead of the segregated tender, and another marker to indicate the end, and the dispatcher is notified. It is interesting to note that "flags" traverse as much as 300 miles of pipe line before dissipating.

In the course of its transportation this particular tender may move through 400 miles of pipe line and may be pumped by eight sets of reciprocating pumps and eight multistage centrifugal pumps. The tanks at reciprocating pump stations are equipped with floating roofs and are used because of their ability to maintain positive suction heads rather than to provide storage for large volumes. The line losses are less than 0.5 percent and when the high volatility of the product is considered, this is not excessive.

In conclusion one cannot emphasize too strongly the need for meticulous care when repairing and overhauling pumping machinery. The policy of anticipating trouble rather than waiting for the inevitable breakdown has averted what might have been serious interruptions in pumping schedules.



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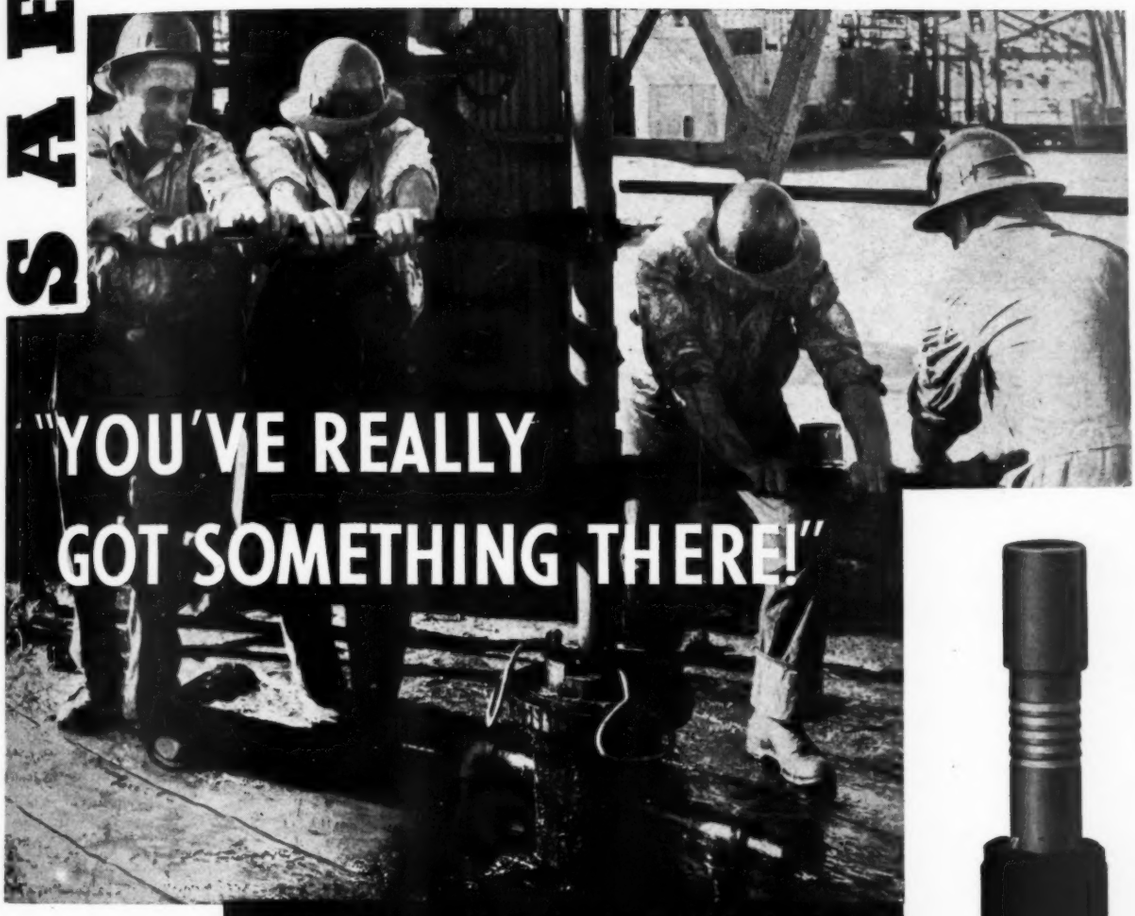

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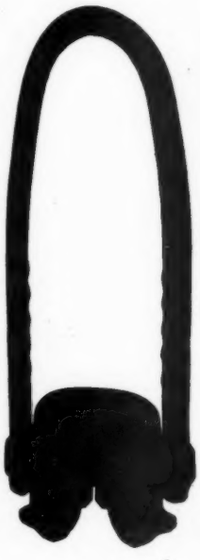

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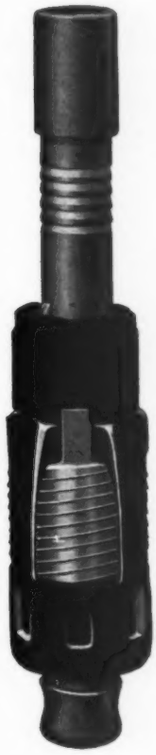

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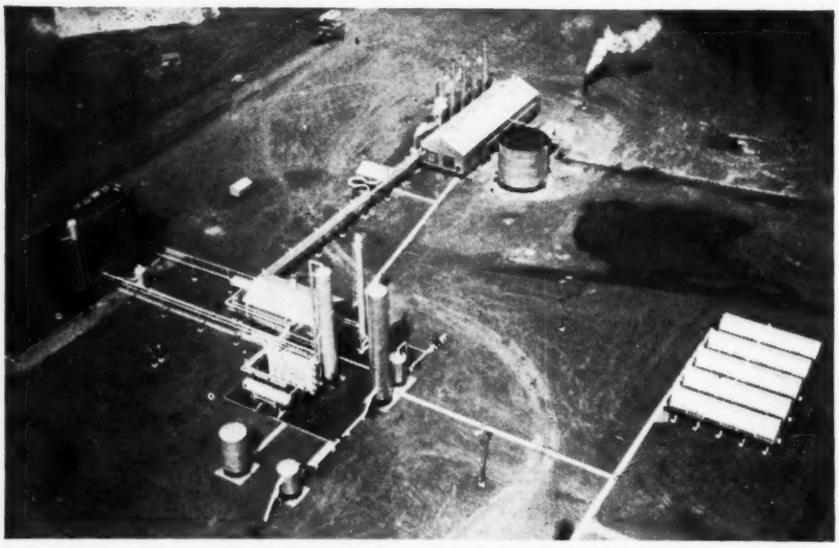

Aerial view of a Mid-Continent natural gasoline plant

By
JOE MILLER
Assistant Superintendent, Natural Gas and Gasoline Department, Humble Oil and Refining Company

Present-Day Trends in Design and Construction of Natural Gasoline Plants

FOR some time the natural gasoline industry has required gasoline plants of special design and construction rather than plants built according to a conventional pattern. This specialization is especially important at the present time. These demands might be created by economic factors or by the need for special hydrocarbons, but regardless of the cause of the demand the natural gasoline industry, through the diligent work of its management and engineers, has been able to meet the situations as they arise.

Additional need for lighter hydrocarbons to be used as liquefied gases and polymerization stock has played a large part in the designing and the redesigning of natural gasoline plants. This has been true particularly in the East Texas field. When the gasoline plants were originally installed in East Texas, there were no indicated demands for lighter hydrocarbons such as propane and butane except possibly as liquefied gases for use as industrial and domestic fuel or, for butane, in the blending of motor fuel. The development of the polymerization plant, however, changed the picture.

It will be interesting to note how a few of these East Texas plants were revamped to obtain maximum butane recovery. As East Texas gas contains approximately four gal. of butane per M. cu. ft. of gas, special provision had to be made to overcome heat of absorption, in addition to the other problems involved. One plant, which as constructed had a conventional 35-lb. absorption unit, has recently made use of propane refrigeration on absorber intercoolers and on the mineral seal oil. Considerable use has been made of both cold vents and hot vents in relieving the loads of different pieces of equipment. Also, increased efficiency of absorption has been obtained by the use of oil of low molecular weight in the main absorbers and special flashed oils in the re-absorber.

Several vapor-rectification plants have been modified to obtain higher butane extraction by using propane refrigeration to obtain lower top temperatures on the primary rectifying column, and by re-cycling the excess propane from the secondary stabilizer to the primary column.

Two high-pressure oil-absorption plants operating at 300-lb. gauge pressure have, in changing over to 95 percent butane recovery and 70 percent propane recovery, made use of water intercoolers on the absorbers. These intercoolers were arranged to remove equal amounts of heat. Stabilized gasoline is put into the still overhead in order to aid condensation. Cold and hot vents have been used to advantage in these plants. A flow sheet for one of these plants is shown as an accompanying illustration.

A high-pressure absorption plant[1] was installed recently in the Gulf Coast area. This plant operates at an absorber pressure of 825 lb. gauge and is designed for 95 percent butane recovery.

A low-pressure, low-temperature compression plant has been constructed and placed in operation in Southwest Texas since the first of the year. This plant makes use of sub-zero gas temperatures obtained by dehydrating the gas and cooling it by propane refrigeration.

Plants to handle the gas from distillate wells have been designed and constructed during the last year. Most of these plants make use of efficient scrubbers and refrigeration of the gas. Considerable work probably will be done on the processing of gas from distillate wells in the near future.

A few of the features incorporated in recent plant design to meet special conditions, but which might not indicate definitely the trend of the natural gasoline industry are listed:

(1) The use of direct-fired heaters and reclaiming units to replace steam heating.

(2) The elimination of multiple absorbers, still retaining large gas-passing capacity and efficiency at the low volumes resulting during Texas' Saturday and Sunday shut-downs.

(3) The installation of additional heat-exchanger surface, which in turn reduces steam consumption and load on cooling towers.

(4) The use of refrigeration to cool oil and gas, thereby increasing recovery and capacity.

(Continued on Page 70)

[1]This plant was described in the October, 1937, issue of *The Petroleum Engineer.*

ABOVE Thompson Field, South Texas, this unit has been in continuous service for 3 years and has handled more than 2,500,000 barrels of crude. At 860 r.p.m. the operating pressure is 640 pounds; the capacity 185 barrels per hour. This unit is Type 6FB5.

ABOVE In 4 months of continuous service, this unit handled 1,000,000 barrels of crude in the Rio Bravo Field, California. It operates at 1,400 r.p.m. at 300 pounds pressure and at a capacity of 310 bbls. per hour. Type 6FB5.

RIGHT A stationary unit which has given 2 years continuous service in the Monument Area near Eunice, New Mexico. Type 4FB8.

LEFT BELOW This stationary unit, Type 4FB8, is giving satisfactory service in the East Texas Field, operating at 1,600 r.p.m. and at 600 pounds operating pressure handles 167 barrels per hour.

RIGHT In service in North Central Texas, this trailer mounted unit, Type 3FB8, illustrates the advantages of an easily portable high pressure pump. Its capacity is 65 barrels per hour at 1,600 r.p.m. with an operating pressure of 450 lbs.

Advantages of this Pump

- Lighter in weight—sturdy yet compact
- Higher efficiencies at Constant High Pressures
- Hardened steel gears—long life assured
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(Continued from Page 66)

(5) The gas-lifting of water over cooling towers, obtaining work from residue gas.

(6) The use of residue gas in turbines for driving pumps and generators, which in turn reduces the steam and power load.

(7) The use of absorption oil of low molecular weight.

(8) The use of reclaiming stills for reconditioning absorption oil.

(9) The installation of ample automatic control equipment to reduce manual control to a minimum.

(10) The control of boiler feed-water and process water by chemical treatment for scale and algae.

(11) The approach of a completely closed boiler feed-water system by the use of a 2- or 3-stage condensate return and by the use of exhaust steam from the pumps for processing, thus eliminating water treatment and reducing load on boilers by returning water at higher temperature.

(12) The use of continuous blow-downs on boilers in order to keep concentration of salts in boiler water low.

(13) The elimination of standby equipment in order to decrease investment. Some plants recently built have entirely eliminated standby equipment. It will be interesting to observe these plants as time passes to ascertain whether or not the cost of down time would off-set the investment in stand-by equipment.

(14) The installation of ample fire-fighting and safety equipment strategically situated around the plant, such as snuff lines that are designed to shut off the boiler fuel and introduce live steam into the fire boxes, make rooms, and pump rooms in case of an emergency, and protection of compressor cylinders from fluid by an arrangement that shorts the magnetos if fluid enters the inlet scrubber.

(15) The use of air and "lube" oil filters.

(16) The use of centrifuge machines to clean lubricating oil.

(17) The installation of all headers in a pipe trench and all valves on suction and discharge lines outside the compressor building.

A few of the general trends in natural gasoline plant construction are as follows:

(1) Whenever possible, all lines are located above ground.

(2) All buried lines are usually protected from corrosion by doping and wrapping.

(3) Care is taken in placing the equipment on the plant site. The location of lines and fittings are carefully planned in order to keep the operating aisles clear.

(4) Most pressure vessels now being installed are designed and constructed in strict accordance with the API-ASME code for unfired pressure vessels.

(5) Some companies are going to the expense of stress-relieving all welded vessels and X-raying those vessels operating under high pressures.

(6) Towers are usually designed to be self-supporting.

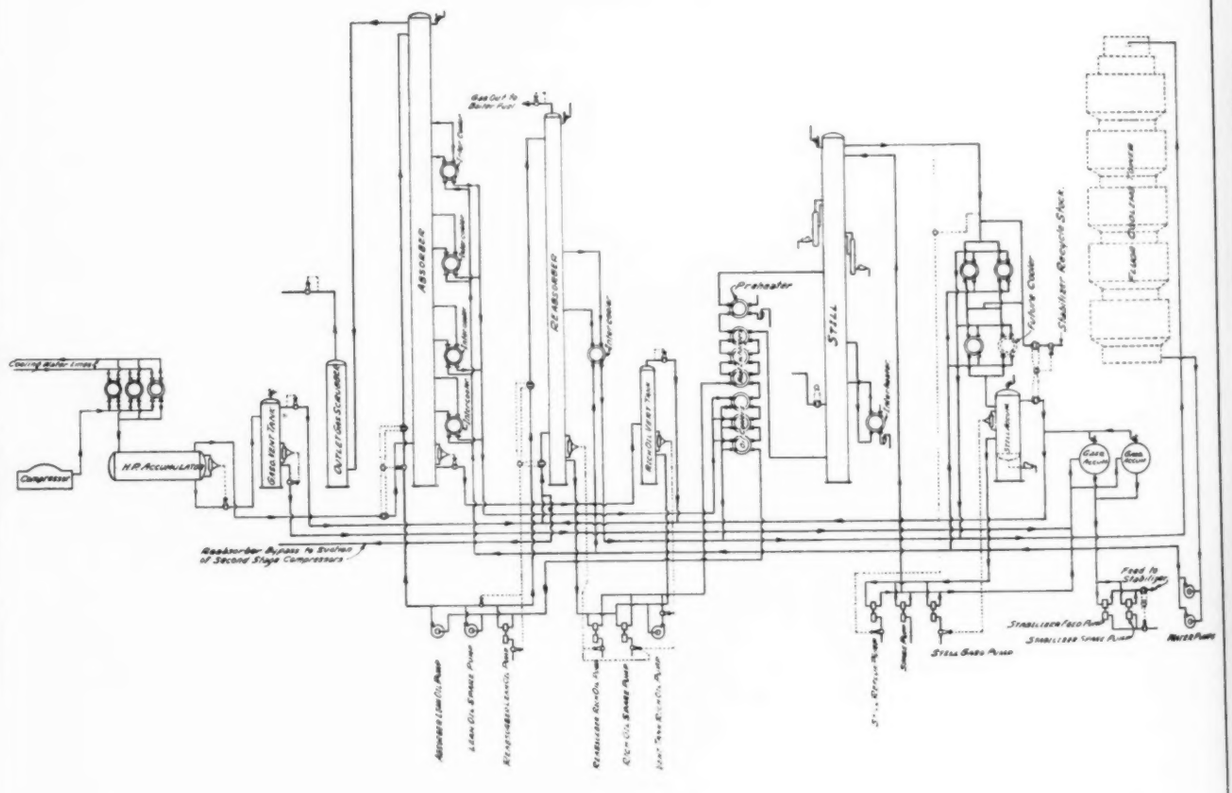
(7) The use of welded lines and fittings is practically standard practice.

(8) Equipment is arranged for both ease of operation and cleanliness.

(9) The installation of showers and locker rooms that are easy to maintain in a sanitary condition tends to create an environment that aids safe and efficient operation.

(10) The general appearance of most gasoline plants now being built is considerably improved by the planting of shrubs and grass.

Flow sheet of a high-pressure absorption-type natural gasoline plant



WATCHING LIFE BEGIN for an AXELSON PUMP

2. The first assembly operation consists of inserting liners into pump jacket. Note that faces of liners are carefully cleaned before inserting.

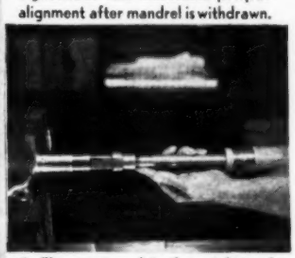
3. Collars are then loosely screwed into both ends of the pump jacket. Interior of liners is flooded with oil to insure proper lubrication.

4. The mandrel is now inserted through the entire length of the pump jacket, thus bringing the liners into proper alignment.

5. While mandrel is still inserted, collars at each end of jacket are tightened. This maintains proper alignment after mandrel is withdrawn.

6. Making up the plunger assembly is the next step. The adapter for the pump rod is screwed tightly into the upper end of the plunger.

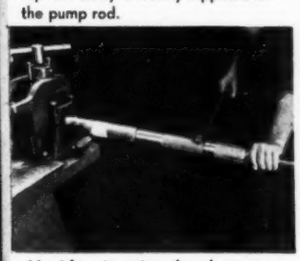
7. The rod guide is now assembled to the top-lock body. This assembly is then slipped over the pump rod.



8. The pump rod is then tightened into the plunger adapter, and the top-lock body is loosely slipped over the pump rod.

9. Seat and ball is now inserted into the lower end of the plunger and the Perry nut tightened against seat. This completes plunger assembly.

10. The plunger assembly, now complete, is inserted into the pump barrel, which has been properly aligned, as described in No. 4.

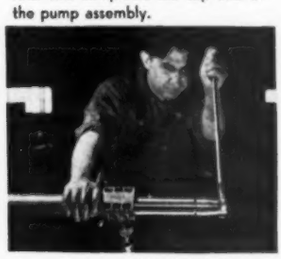


11. After inserting the plunger assembly into pump barrel, top-lock body and rod guide are tightened into top collar of pump barrel.

12. Next, the pump rod coupling is securely tightened onto the pump rod. This completes the top end of the pump assembly.

13. It is now necessary to complete the bottom end of the pump. The double valve cage is now screwed into the combined collar and cage.

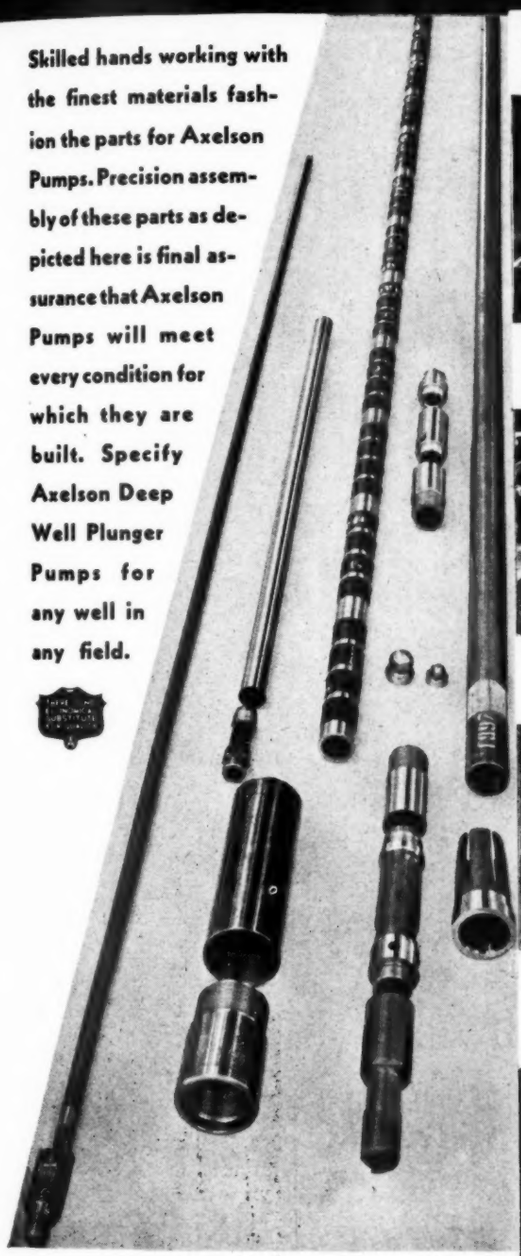
14. The seat and ball is then inserted into the double valve cage. Seat and ball have been previously vacuum tested for perfect seating.



15. The seat and ball is held into place by the standing valve body. This standing valve body acts as a pilot when lowering pump into well.

16. The locking assembly is now made up and secured by the clamping collar. The pump is now oiled and painted, and boxed for shipment.

Skilled hands working with the finest materials fashion the parts for Axelson Pumps. Precision assembly of these parts as depicted here is final assurance that Axelson Pumps will meet every condition for which they are built. Specify Axelson Deep Well Plunger Pumps for any well in any field.



1. Here are the parts for an Axelson R. S. L. stationary barrel type pump, with top-lock hold-down, Perry Barnwell plunger, combined collar and cage, hardened cast iron liners and Axloy seats and balls.

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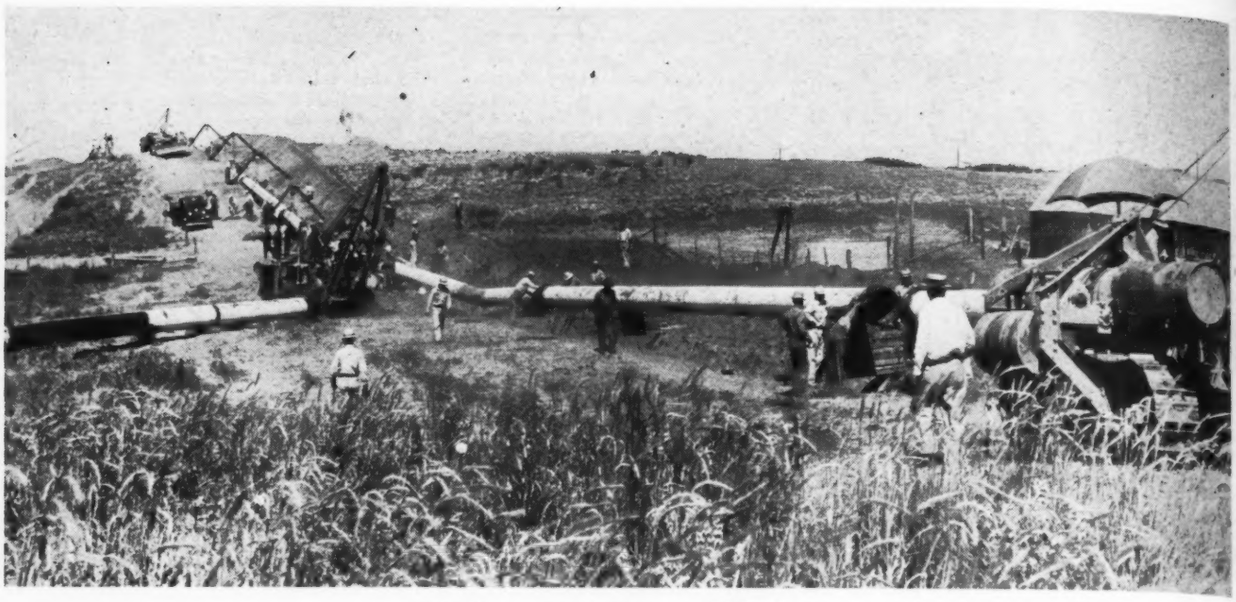

Making a sag bend in a 24-in. loop (*Photo Courtesy The Barrett Company*)

Recent Developments and Trends in the Construction, Operation, and Maintenance of Pipe Lines

By J. STANLEY STEVENSON

Chief Engineer, Panhandle Eastern Pipe Line Company

THE pipe-line division of the oil and gas industry during the last year has not developed revolutionary methods of construction or operation; it has received no front page publicity in large city dailies because of major achievements of engineering; but progress has been made, there is no denying that. Trends toward increased application of engineering and technology have continued; operation and maintenance practices have improved; better pipe and materials have been made; and more powerful and efficient equipment has been produced. This brief review can do little more than outline a few of the more important trends and modern practices and does not list these in the order of their relative importance.

Developing and Maintaining High Flow Efficiencies of Pipe Lines

Long distance transportation of natural gas, in one line over a distance equivalent to more than half the entire width of the southern part of the United States, emphasizes the economic importance of the efficiency of flow of these cross-country pipe lines. This trend toward better pipe-line transportation performance calls for efficiency tests of gas flow, which are being made at periodic intervals by some gas companies. It is obvious that before the efficiency of a pipe line can be determined it is necessary to establish a standard, or yardstick, to which actual flows under operating conditions may be compared. This "standard pipe line," possessing 100 percent flow efficiency, would be straight and level and would have an unvarying internal diameter and polished interior walls.

As commercial line pipe cannot be made and maintained absolutely circular and smooth, and, if so made, could not be laid perfectly straight and level and without joint irregularities, pipe lines can only approach the perfection of a "standard pipe line" in varying degrees dependent on the roughness of the interior walls, number and type of joints, grade of the line, and number and magnitude of bends or changes of direction, horizontally and vertically.

Field tests of the flow of gas through a pipe line consist, essentially, of carefully observing dead-weight readings of the pressure of the flowing gas at several points along the section of line under test. Pressures are recorded only after a uniform flow velocity has been maintained long enough to assure stable pressure and flow conditions. Gas temperatures and the barometric pressure are noted and the volume of gas passed during the period of the test, as measured through a check meter station, is calculated.

As a measure of the perfection of the lines under observation the flow of gas under actual conditions is then compared to the flow that would have occurred in a standard line of the same diameter, under similar conditions of initial (upstream) pressure, gas temperature, and length of line. The ratio of the actual flow, as measured, to the flow that would have occurred in a perfect line under these conditions gives the flow efficiency of the tested line.

The selection of the formula used in calculating the flow through the standard pipe line is important if accurate

Lining-up 12-in. pipe in construction of the Hope Natural Gas Company's line

(Photo Courtesy The Lincoln Electric Co.)

comparisons of efficiencies are to be attained under various conditions of flow. The friction factor in the fundamental flow formula is a function of the diameter of the pipe and of the various qualities of the gas but does not recognize the effect of varying velocities of the flowing gas. Consistently accurate results cannot be expected unless the formula takes into consideration the effect of changes of gas velocity.

Gas engineers have recently used a friction factor developed by Nikuradse and published in 1932. Substituting this factor, which corrects for variations of flow due to varying velocities of the flowing gas, in the fundamental flow equation, consistent comparisons of efficiencies have been made. The use of Nikuradse's factor somewhat complicates flow calculations but this difficulty is overcome by plotting a coefficient of friction curve for values of "MCF per 24 hours per in. of pipe diameter" and pressure-drop curves for each section of pipe line involved in the flow studies. Engineers find they are well repaid for the time required in calculating and plotting these curves, particularly if a series of flow studies is required.

The efficiency of a pipe line is one measure of the transportation value of the line; it provides a gauge of the line's original usefulness and provides a means of checking whether its initial efficiency is being maintained; it is a test of pipe-line design, materials, and construction; and it gives a means of calculating accurately additional pipeline facilities required for increased deliveries, in which respect a knowledge of flow efficiency is particularly useful when designing loops for an existing line.

Faced with the necessity of constructing loops or additional compressor facilities or of restoring the original flow efficiency of their main lines several gas companies have successfully cleaned their lines, restoring all or a large part of the lost capacity. Various methods of cleaning the interior of gas lines are being used, some with a greater measure of success than others. Probably the most interesting development in this field, although commonly used for years in cleaning oil and gasoline lines, is a "go-devil", or scraper, especially designed for use in cleaning gas lines. Use of a scraper designed for a 22-in. gas line increased the carrying capacity of an 86-mile section of a gas transmission line of this size more than 20 percent. The capacity of the line after being cleaned was nearly 7 percent greater than when it was originally constructed.

The body of this scraper was made of 20-in. pipe and a 20-in. by 18-in. swedge welded together. Openings were cut in the body to reduce its weight to approximately 800 pounds. The speed of the scraper through the pipe line is regulated by maintaining the proper pressure differential across the device. The average velocity of scraper travel is between 20 and 25 miles per hour. Gas enters the openings in the side of the scraper just ahead of the steel blades and passes through the opening at the forward end, carrying the loosened materials in the gas stream to the end of the section of pipe line being cleaned, where they are blown into the air. The blades themselves are made of tool steel, placed at an angle of 45 deg. to the axis of the scraper. Three rows of blades are provided. Contact of the blades with the surface of the pipe is maintained at a constant pressure by mounting the blades on coil springs.

Other methods of maintaining flow efficiencies are being used successfully, the selection of each method being determined by a study of the condition of the internal walls of the pipe, the nature and extent of the obstructing materials, design and construction of the pipe line, its load factor, and other operating conditions. High efficiencies are being maintained in some lines merely by blowing the line at regular intervals. This method is generally effective in lines obstructed only by liquid accumulations.

Steel shavings or lathe cuttings, blown through a line at high velocity, have produced excellent results. The

(Continued on Page 78)

Tightening coupling bolts on a 24-in. line. The pipe is coated with enamel and protected against the sun's rays by a whitewash coat

(Photo Courtesy The Barrett Company)

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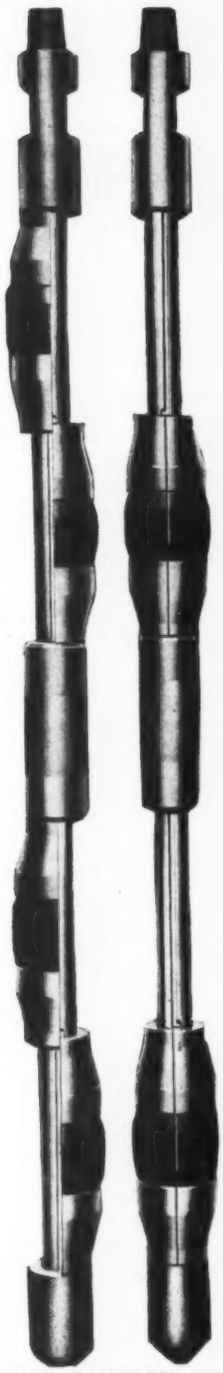

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Swab 3 to 15 times faster—with SAFETY ... because of the Mission split-rubber principle . . . ON DOWN STROKE the movable half of each rubber rises above stationary half, allowing an area for fluid passage much larger than that of conventional type swab ... ON UP STROKE movable half of each rubber drops back beside its other half.

That's Why . . .

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(Continued from Page 75)

practice established by one company calls for the installation of a "purge joint" at the mid-point between main-line gates. The five-mile section of pipe between gates is blown down, connections are made at a point about half way between the gates, and a purge joint is inserted. This is a 12-ft. piece of pipe of the same diameter as the line being cleaned. It is welded to a tee connection fitted with flanges for convenient connection to the line, replacing a flanged nipple of the same length. Steel shavings—some two or three bushels—are introduced into a section of the line through bleed-off valves at the main-line gates. Shavings are blown downstream and discharged through the purge joint together with all loosened materials. The other half of the pipe-line section is then cleaned, shavings being blown upstream to the purge joint in the same manner. Men stationed at main-line gates are in constant telephone communication with the line superintendent, who remains at the purge joint during the cleaning.

Scrubbers have been in common use on gas lines for years, proving of great value in cleaning the gas stream of harmful foreign matter, thereby protecting gas compressors, meters, and appliances and assisting in maintaining high pipe-line flow efficiencies. A Mid-Continent pipe line company engaged in long distance transportation of gasoline met a serious cleaning problem three years ago by installing cleaners designed by its engineers. The principle of reduced flow velocity and screening has been applied to the construction of these cleaning vessels, which are 42 in. in diameter by 6 ft. high. They are known as "tank" type or "low velocity" cleaners.

The flow of gasoline through the tanks is upward. The reduced velocity of the gasoline stream permits foreign matter in the gasoline to settle in a sediment chamber at the bottom. Gasoline leaves the tank at the top after passing through an excelsior screen. The original installations proved so satisfactory that additional cleaners were installed in 1936. Two tanks were installed aboveground at the intake side of each pump station, one tank being on stand-by service. Recently another large Mid-Continent company, after making a close study of this type of cleaner, prepared to make similar installations on its gasoline lines.

Cathodic Protection Association Formed

Cathodic protection of underground pipe lines, an electrical method of protection practically unheard of ten years ago, is steadily increasing in interest and importance to the industry. Hoping to profit by a collective comparison and study of information that will aid in the proper installation of this method of protection, several corrosion engineers and others interested in pipe protection formed the Mid-Continent Cathodic Protection Association, at Houston in March, 1938. Thirty-eight representatives of pipe line companies operating principally in Texas, Oklahoma, and Louisiana, were present at this initial meeting.

The formation of an association of this nature is a natural step by pipe line companies in their effort to keep installation and operating methods in pace with marked improvements constantly being made in cathodic protection equipment. In addition to apparent advantages to be gained by its members in pooling their experiences and keeping abreast of new trends and developments in this field of pipe-line protection it is planned to make the association a medium of exchange of information relative to the location of all present and future cathodic installations. In this manner the management of a pipe line company will be advised of any proposed installation by another company that might affect its lines.

Wrinkle-Bending

Wrinkle-bending as now being practiced in pipe-line construction cannot be considered a new development in the field fabrication of pipe lines. The process was known 25 years ago but only recently has it come into extensive use. It may be included with "stove-pipe" welding in a trend toward the use of lighter pipe line construction equipment in areas not readily accessible. Wrinkle-bending is particularly advantageous in mountainous country where, obviously, the greatest number of pipe bends is necessary, and in low, swampy areas.

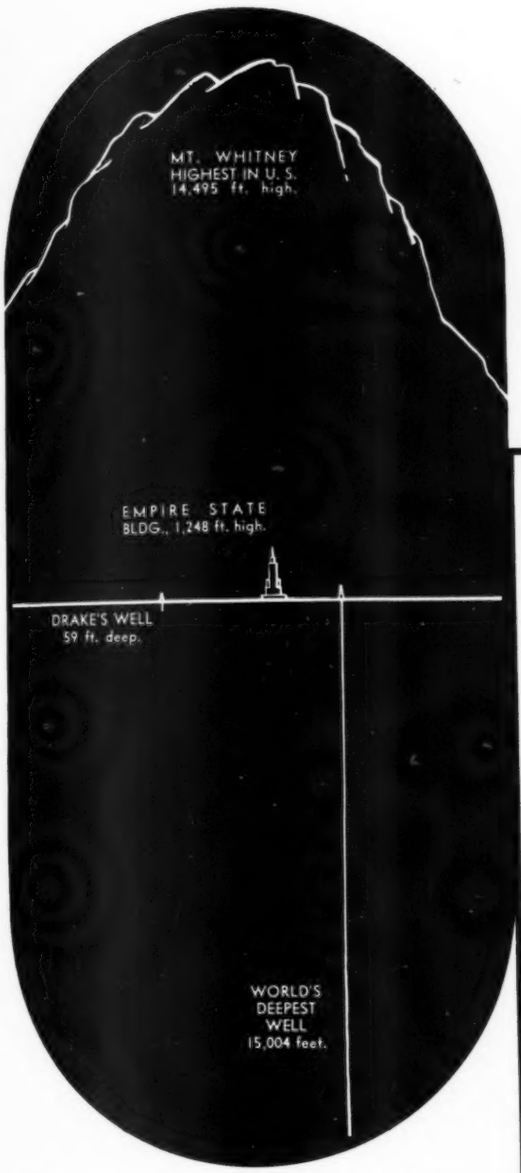
The procedure consists, essentially, in heating the pipe with an oxy-acetylene flame in one or more narrow bands at right angles to the longitudinal axis of the pipe and then utilizing the weight of the pipe to form the bend. Any number of bands may be heated, several being required to produce a decided change in direction.

The principal advantage of wrinkle-bending has been mentioned. There are several other noteworthy advantages, the principal one relating to wall thickness. The pipe is bent toward the heated side, throwing the heated band under compression and forming a wrinkle projecting outward. The pipe wall opposite the wrinkle retains its original thickness and the compression actually increases the thickness of the wall at the wrinkle. As the wrinkles project outward they offer no restriction to gas flow. Long radius bends, so desirable in producing an efficient pipe line, are easily fabricated at a low cost.

Wrinkle-bending is applicable to any size pipe, heavy-wall and light-wall, in

Laying a 22-in. gas line by the stove-pipe method, using a Crockett grasshopper to help line-up the joints. The weld is being made with acetylene

(Photo Courtesy Air Reduction Sales Company)



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PROGRESS OF DEEP DRILLING

1920 (Under)	10,000 ft.
1927	12,000 ft.
1928	13,245 ft.
1929	13,901 ft.
1930	14,314 ft.
1931	15,004 ft.

OIL PRODUCTION IN U. S.

1859	2,000 Barrels
1900	63,620,000 "
1920	442,929,000 "
1930	898,012,000 "
1931	851,087,000 "
1932	785,151,000 "

CALIFORNIA

WELL AND LOCATION	DEPTH FT	DATE COMPLETED	REMARKS: Records Established, Casing Set, Etc.
Continental Oil Co. • C. E. K. R.E. Ware area, Kern Co.	15,004	April 1938	Now the World's deepest well. Casing @ 80' - 10¾, @ 1,500' - 7" @ 5,760'. Has been the world's deepest well but one for months. Flow 1,000 B. P. D. with 1,000 gas well.
Superior Oil Co. and Union Oil Co. • Ken Land & Inv. Co. Section, Kern Co.	12,618	July 1937	Unproductive deep test. Once deepest in California. Fourth deepest in world. Casing @ 12,618'.
Kettleman North Dome Association • R.B. 1, Kettleman Hills, Kern Co.	11,946	Dec. 1937	Producing 850 bbls. Casing @ 11,946'.
Superior Oil Co. • Kahl • Rio Bravo District, Kern Co.	11,430	Drilling	Casing @ 11,430'.
General Petroleum Corp. • Berry • Belridge, Kern Co.	11,377	June 1938	
Superior Oil Co. • Wagner 2 • Rio Bravo District, Kern Co.	11,330	Drilling	Casing @ 11,330'.
Union Oil Co. • Bell 182 • Santa Fe Springs field, Los Angeles Co.	11,314	Mar. 1938	One of the deepest producers in world. Casing @ 11,314'.
Union Oil Co. • Kern 1 • Rio Bravo area, Kern Co.	11,302	Nov. 1937	Second deepest producing well in world. Completed in 1938 sand. Casing @ 11,302'.
Superior Oil Co. • Stevinger 1 • Rio Bravo District, Kern Co.	11,280	Mar. 1938	Casing @ 11,280'.
Superior Oil Co. • Wagner 1 • Rio Bravo District, Kern Co.	11,260	Mar. 1938	Casing @ 11,260'.
Union Oil Co. • Kern 1-34 • Rio Bravo area, Kern Co.	11,206	Drilling	Casing @ 11,206'.
Standard Oil Co. • Mono 1 • Tulare area, Tulare Co.	11,200	Drilling	No drawing reported. Last casing string @ 11,200'.
Union Oil Co. • Kern 1 • Kern County, North Kettleman Oil & Gas Co. • Kettleman Hills, Kern Co.	11,147	Sept. 1936	Dry hole. Strong pressures encountered. Casing @ 11,147'.
Amer. Trading Co. • Kern 1 • Rio Bravo District, Kern Co.	11,085	Drilling	Casing @ 11,085'.
Standard Oil Co. • R.E.L. 1-A • Elk Hills District, Kern Co.	10,885	Casing	Casing @ 10,885'.
Kern Oil Co. • SR. 1 • Kern District, Fresno Co.	10,875	Drilling	Casing @ 10,875'.
Tidewater Associated Petroleum No. 18 • Belridge,	10,870	April 1938	Casing @ 10,870'. Reworking Producing.
Standard Oil Co. • 27-B-2 • Kettleman Hills, Kern Co.	10,796	Drilling	Casing @ 10,796'.
Superior Oil Co. • Huffman 5 • Kettleman Hills, Kern Co.	10,748	Feb. 1938	Drilled deep but not productive. Casing @ 10,748'.
Tide Water Associated Oil Co. • McGarrigle 1 • Ventura Ave. Ventura Co.	10,650	Feb. 1938	Casing @ 10,650'.
Kettleman North Dome Assn. • 27-D-1 • Kettleman Hills, Kern Co.	10,566	Drilling	Casing @ 10,566'.
Union Oil Co. • Chapman 29 • Lemon area, Orange Co.	10,495	Feb. 1938	Casing @ 10,495'.
Union Oil Co. • Carleton 14 • Dominguez field, Los Angeles Co.	10,435	May 1937	Unproductive bore hole. Casing @ 10,435'.
Warren-Bell Oil Co. • Bradley 1 • Santa Maria, Santa Barbara Co.	10,396	July 1932	Dry hole. Was deepest test in U. S. for and second deepest in world. Casing @ 10,396'.
Kettleman North Dome Assn. • 34-E-2 • Kettleman Hills, Kern Co.	10,350	June 1938	Unproductive. Flowed 20 BOPH. Casing @ 10,350'.
Seaboard Oil Corp. & Tide Water Associated Oil Co. • R.E.L. 1-C • Elk Hills area, Kern Co.	10,344	July 1937	Suspended July 15 1937. Casing @ 10,344'.
General Petroleum Corp. • Wagner • Rio Bravo District, Kern Co.	10,109	Drilling	Casing @ 10,109'.
Amerada and Oil Co. • Lloyd 17 • Fullerton Ave. Field	10,060	Dec. 1937	Oil well, initial production 1000 bbls. daily. Casing @ 10,060'.
Atlantic Ref. Co. • Adobe 1 • Lando area, Kern Co.	10,056	July 1937	Dry hole. Casing @ 10,056'.
Chanslor-Canfield-Midway Oil Co. • Hobson A-2 • Kreyer, Fairfax Co.	10,030	May 1931	Unproductive deep test. First zone drilled to 10,030'. Casing @ 10,030'.
Pan Tenn Co. • E. E. L. C-149 • Kern Co.	10,016	Oct. 1936	Unproductive. Casing @ 10,016'.
Superior Oil Co. • Waggoner No. 1 • Rio Bravo,	10,003	Drilling	No drawing reported. Casing @ 10,003'.

LOUISIANA

Standard Oil & Gas Co. and Amerada Pet. Corp. • Calcasieu, Nos. 16, 18 South Sher. Jeff. Davis Parish	13,210	Drilling	Casing @ 13,210'. Second deepest test in the world.
The Texas Co. • Horseshoe Bayou • Horseshoe Bayou Field, St. Mary Parish	12,351	Nov. 1937	Drilling @ 12,351'. 30 gravity oil on production at 12,062'-12,072 ft. 10th in world to reach 12,000 ft. Shot and deep 30, 1937. Burned 1 hr. bridged. Casing @ 10 in. - 12¾ @ 6,496 ft. - 7¾ @ 12,496 ft.
Continental Oil Co. • Hebert 1 • Abbeville, Vermilion Parish	12,216	Dec. 1936	Production at 7000 ft. after plugging back. Still deepest test in world. Second 12,000-ft. hole in Louisiana. Second largest casing string, largest at time. Strong showings at 12,216 ft. Sanded in at 12,216'. Casing @ 12,216'.
Humble Oil & Refining Co. • Blender 1 • Lirette field, Terrebonne Parish	12,165	Mar. 1937	Now producing from 12,025 ft. after plugging back. Was world's deepest producing well. Flowed 1000 bbls. choked after plugging back to 11,600 ft. Flow 11,000 B. P. D. through 24/64 choke with 1,000 lbs. tubing pressure. Gas-oil ratio 1,000 cu. ft. per bbl. Gravity 40° A.P.I. Deepest producing well in world. Drilled 12,165 ft. Casing @ 12,165'.
Standard Oil & Gas Co. • Stovall 1 • South Abbeville, Vermilion Parish	12,138	Jan. 1937	Dry hole. Third test to reach 12,000 ft. Eighth deepest ever drilled. Record for amount of open hole. Having had 10,410 ft. unpaced. Casing. Only surface pipe at 1,900 ft.
The Texas Co. • Norman No. 1 • Lirette area, Jefferson Parish	12,115	Drilling	Producing @ 9,610 ft. Casing. 10¾ @ 10 ft. - 7⅝ @ 10,451 ft. - 5½ @ 9,604 ft.
The Texas Co. • Delta Duck Farms • Lafitte field, Jefferson Parish	12,115	Nov. 1937	Tried to blow out at 12,085 ft. Plugged back, perforated 9530-9600 ft. made 1750 bbls. daily. Casing. 10¾ @ 10 ft. - 7⅝ @ 10,451 ft. - 5½ @ 9,604 ft.
Continental Oil Co. • Drelichia 1 • Abbeville field, Vermilion Parish	11,909	Sept. 1937	Blew out at 11,909 ft. made 10,000 bbls. with water, plugged back and perforated in sand at 9200-9300 ft. on oil well. Casing. 10¾ @ 20 ft. - 7⅝ @ 10,451 ft. - 5½ @ 9,604 ft. Changed string 7⅝ in casing.
The Texas Co. • Bateman Lake • Bateman Field, St. Mary Parish	11,879	Dec. 1937	Deepest producing well on Gulf Coast. Completed on oil well at 11,879'. Casing. 10¾ @ 20 ft. - 7⅝ @ 10,451 ft. - 5½ @ 9,604 ft.
E. W. Gardner • Payne 1 • Caddo Parish	11,686	Drilling	
Rels Oil Co. and Hagen Bonte Co. • Sims 1 • Lake Long field, La Fourche Parish	11,347	Feb. 1938	Casing. 10¾ @ 10,451 ft.
The Texas Co. • St. Mary Parish Land Co. • Horse Shoe Bayou, St. Mary Parish	11,027	Drilling	Casing. 10¾ @ 10,451 ft.
Texas Co. • State Lake Bess No. 17 • Terrebonne Parish	10,989	Dec. 1937	Dry. @ 10,989 ft. Re-completed at 9966. Casing. 10¾ @ 10,451 ft. - 5½ @ 9,604 ft.
The Texas Co. • State Lake Bess 57 • Lake Bess, Terrebonne Parish	10,959	April 1937	Production at 10,959 ft. after plugging back. Thirteenth 10,000 ft. test in Louisiana. Coast. Flat in world, and sixth for the company. Casing. 10¾ @ 10,451 ft. - 5½ @ 9,604 ft.
Texas Co. • Egan-Cooperative • Ten No. 3, Lafitte area, Jefferson Parish	10,942	Producing @ 10,451 ft. Casing. 10¾ @ 10,451 ft. - 5½ @ 9,604 ft.
Humble Oil Co. • Barre and Ravine • Jeanerette Field, St. Mary Parish	10,870	Drilling	Flow 10,000 ft. producer at 9,600, oil sand 10,270-10,290 ft. Casing. 10¾ @ 10,451 ft. - 5½ @ 9,604 ft.
Humble Oil & Refining Co. • Frank Wurtzer 1 • Terrebonne Parish	10,782	Abandoned	Casing. 10¾ @ 10,451 ft.
Bernhard Oil Co. • Hank Elder & Brown 1 • north of Bayou Pigeon Field, Terrebonne Parish	10,777	Nov. 1937	Producing @ 10,451 ft. Casing. 10¾ @ 10,451 ft. - 5½ @ 9,604 ft.
Shell Petroleum Corp. • Jernigan 1 • Rayneds, Jefferson Davis Parish	10,700	Sept. 1936	Dry hole. Casing. 10¾ @ 10,451 ft. - 5½ @ 9,604 ft.
Shell Petroleum Corp. • Nelson 1 • Bayou Field, Terrebonne Parish	10,727	Aug. 1937	Dry hole. Casing. 10¾ @ 10,451 ft. - 5½ @ 9,604 ft.
Texas Co. • Lafitte Land & Exp. Co. • No. 10, area, Terrebonne Parish	10,719	Drilling	Casing. 10¾ @ 10,451 ft. - 5½ @ 9,604 ft.
The Texas Co. • Vermilion Bay • Hamilton Bay area, Iberia Parish	10,622	Mar. 1937	Dry hole.
Shell Petroleum Corp. • Unit No. 1 • St. Mary Parish	10,600	Drilling	
Humble Oil & Refining Co. • Hebert 1 • Rayneds, Jefferson Davis Parish	10,563	Sept. 1936	Dry hole. Casing. 10¾ @ 10,451 ft. - 5½ @ 9,604 ft.
Harber Oil Co. • Carter 2 • Jeanerette Field, St. Mary Parish	10,476	Drilling	Casing. 10¾ @ 10,451 ft.
Texas Co. • Egan-Cooperative Fee Co. No. 7 • Lafitte area, Jefferson Parish	10,406	Jan. 1937	Producing @ 10,406 ft. Casing. 10¾ @ 10,451 ft. - 5½ @ 9,604 ft.
Superior Oil Producing Co. • Lacoste 5 Bayou Field, St. Landry Parish	10,392	Drilling	Casing. 10¾ @ 10,451 ft. - 5½ @ 9,604 ft. Was a producer at 10,000 ft. drilled deeper on exploration test to 10,216 ft. Plugged back to 9321 ft. on coring, drilling deeper.
Texas Co. • Louisiana Land & Exp. Co. • Lafitte No. 4, Lafitte area, Jefferson Parish	10,305	May 1937	Producing @ 10,284 ft. Casing. 10¾ @ 10,451 ft. - 5½ @ 9,604 ft.
Superior Oil Producing Co. • Duplantier 1 • Baton Rouge area, East Baton Rouge Parish	10,260	Oct. 1937	Producing @ 10,260 ft. Casing. 10¾ @ 10,451 ft. - 5½ @ 9,604 ft.
Pan American Prod. Co. • State 1-A • St. Mary Parish	10,217	Feb. 1938	Plugged back and completed @ 9,660 ft.
Amerada Pet. Corp. • A. B. Lott & Sons • South Coast Corp. • Rayneds, Jefferson Davis Parish	10,214	Jan. 1938	Casing. 36 @ 322 ft. - 22¾ @ 10,214 ft. - 7⅝ @ 9,901 ft. Oil sand at 10,100 ft. - 132 B.O. through ¾ inch choke. Producing.
Rels Oil Co. • Buckley No. 1 • State area, Terrebonne Parish	10,113	Drilling	
Texas Co. • Egan-Cooperative Fee Co. • No. 8, Lafitte area, Jefferson Parish	10,086	Drilling	Producing @ 10,004 ft. Casing. 10¾ @ 10,451 ft. - 5½ @ 9,604 ft.
The Texas Co. • Warren No. 1 • Lafitte field, Jefferson Parish	10,075	Feb. 1938	Blew out, flash-fired and caving @ 10,040 ft. Logged, cored @ 10,040-10,075 ft. Casing. 10¾ @ 10,451 ft. - 5½ @ 9,604 ft. Producing.
The Texas Co. • Louisiana Land & Exp. Co. • Lafitte No. 7, Lafitte area, Jefferson Parish	10,075	Mar. 1938	Producing @ 10,075 ft. Casing. 10¾ @ 10,451 ft. - 5½ @ 9,604 ft.
Humble Oil & Refining Co. • Sevier • South Country area, Arcadia Parish	10,272	Drilling	Casing. 10¾ @ 10,451 ft. - 5½ @ 9,604 ft. Tried to blow out at 10,451-10,504 ft. Kelsey 10,272 ft.
Humble Oil & Refining Co. • Commercial Fee • Crystal area, Terrebonne Parish	10,254	Sept. 1936	Dry hole. Casing. 10¾ @ 10,451 ft.
The Texas Co. • Louisiana Land & Exp. Co. • Lafitte No. 9, Lafitte area, Jefferson Parish	10,107	May 1938	Producing @ 10,107 ft. approx. 10¾ @ 10,451 ft. - 5½ @ 9,604 ft. Producing @ 10,098 ft.
Shell Petroleum Corp. • Keefe, 1 • Houma area, Terrebonne Parish	10,157	Mar. 1936	Dry hole. Casing. 10¾ @ 10,451 ft. - 5½ @ 9,604 ft.
The Texas Co. • Welfare Bay 1 • Carencro Parish	10,146	Mar. 1937	Dry hole. Casing. 10¾ @ 10,451 ft. - 5½ @ 9,604 ft. - 5½ @ 9,604 ft.
Humble Oil & Refining Co. • Main • Caffin Lake, Cameron Parish	10,133	Drilling	Casing. 10¾ @ 9,920 ft. - 5½ @ 9,604 ft.
Union Producing Co. et al. • Bromfield No. 1 Sugar Creek area, Claiborne Parish	10,130	Drilling	Casing. 10¾ @ 10,451 ft. - 5½ @ 9,604 ft.
Texas Co. • Louisiana Land & Exp. Co. • Lafitte No. 11, Lafitte area, Jefferson Parish	10,130	Dec. 1937	Producing @ 10,130 ft. Casing. 10¾ @ 10,451 ft. - 5½ @ 9,604 ft.
Texas Co. • Louisiana Land & Exp. Co. • Lafitte No. 6, Lafitte area, Jefferson Parish	10,092	Mar. 1938	Producing @ 9,888 ft. Casing. 10¾ @ 10,451 ft. - 5½ @ 9,604 ft. - 5½ @ 9,604 ft.
Texas Co. • Louisiana Land & Exp. Co. • Lafitte No. 9, Lafitte area, Jefferson Parish	10,070	Feb. 1938	Producing, February, 1938. Casing. 10¾ @ 10,451 ft. - 5½ @ 9,604 ft.
Texas Co. • Louisiana Land & Exp. Co. • Lafitte No. 9, Lafitte area, Jefferson Parish	10,066	Sept. 1937	Dry hole. Casing. 10¾ @ 10,451 ft. - 5½ @ 9,604 ft.
Pan American Prod. Co. • Lewis 9 Clarendon Field, St. Mary Parish	10,063	Sept. 1937	Producing @ 10,063 ft. Casing. 10¾ @ 10,451 ft. - 5½ @ 9,604 ft. - 5½ @ 9,604 ft.
Texas Co. • Louisiana Land & Exp. Co. • Lafitte No. 5, Lafitte area, Jefferson Parish	10,057	Sept. 1937	Producing @ 10,057 ft. Casing. 10¾ @ 10,451 ft. - 5½ @ 9,604 ft. - 5½ @ 9,604 ft.
Humble Oil & Refining Co. • Hendrix 1 • South Country area, Arcadia Parish	10,056	Mar. 1938	Producing @ 10,056 ft. Casing. 10¾ @ 10,451 ft. - 5½ @ 9,604 ft.
The Texas Co. • Lafitte No. 9, Jefferson Parish	10,055	Drilling	Showing @ 10,055 - 10,085 ft. Casing. 10¾ @ 10,055 ft.
Texas Co. • Madison Point, No. 1 • Lafitte area, Jefferson Parish	10,040		Casing @ 10,040 ft. approx. 10¾ @ 10,451 ft. - 5½ @ 9,604 ft. approx.
The Texas Co. • R. E. Kelley • Lafitte field, Jefferson Parish	10,040	Jan. 1937	Completed for flow. Oil sand at 10,040 ft. Was stopped 10,000 ft. unperforated well at casing and opened at bottom.
Texas Co. • Egan-Cooperative Fee Co. No. 9, Lafitte area, Jefferson Parish	10,008		Casing. 10¾ @ 10,451 ft. approx. 10¾ @ 10,451 ft. approx.
Texas Co. • Louisiana Land & Exp. Co. • Lafitte No. 10, Lafitte area, Jefferson Parish	10,008		Casing. 10¾ @ 10,451 ft. approx. 10¾ @ 10,451 ft. approx.
Superior Oil Producing Co. • Martinez 1, Bayou Field, St. Landry Parish	10,002	Jan. 1936	Dry hole. 10,000 ft. test in Interstate. Casing. 10¾ @ 10,451 ft. - 5½ @ 9,604 ft.
Gulf Oil Corp. • Thomas 10, Richard Field	10,001	Early 1937	First 10,000 ft. test in North Louisiana.

OKLAHOMA

Gulf Oil Corp. • Thomas • Grady Co.	11,115	Drilling	Casing. 10¾ @ 4000 ft. - 7 @ 9891 ft.
Barnsdall Oil Co. • Ramsey 2-A • Ada-Vici • Creger, Coalgate Co.	11,230	July 1934	Four 10,000 ft. producers but not considered commercial. Made 50 bbls. daily on gas lift from 10,422 ft. Was second 11,000 ft. test in world. Casing. 10¾ @ 10¾ - 7 @ 6996 ft. - 5½ @ 10,422 ft.
Barnsdall Oil Co. • Ramsey 2-B • Ada-Vici • Coalgate Co.	10,806	Mar. 1936	Unproductive. Third 10,000 ft. test in state. Casing. 10¾ @ 10¾ ft. - 7⅝ @ 10,803 ft.
Midland Petrol. Oil & Gas Co. (now Okla. Oil Co.) and Ramsey Petroleum Corp. • Hunter-Cecil 1 • Coalgate,	10,079	Oct. 1931	Unproductive. Flowed 1,000 bbls. salt water. Deepest abandoned. Deepest depth causing string at time. Second 10,000 ft. test in world. Casing. 10¾ @ 60 ft. - 7 @ 9,890 ft. - 4½ @ 10,079 ft.
Cotton Oil Co. • Johnson 1 • Stephens Co.	10,009	Drilling	Drilled 10,000 ft. test drilled in state. Reached depth Oct. 6, 1937. Plugged back to 9160 ft. Casing. 10¾ @ 60 ft. - 7 @ 9,890 ft. - 4½ @ 10,009 ft. Operators were waiting after completion of 8000 ft.

TEXAS

Gulf Oil Corp. • McElroy, No. 10, Ector-McElroy Field, Upton Co.	12,786	May, 1938	World's third deepest test. Unproductive. World's first 12,000 ft. casing string. Four 12,000 ft. hole. Sanded-in March 31. 1938. Second shoe below 12,000 ft. - 7 @ 6996 ft. - 5½ @ 12,786 ft. Casing. 10¾ @ 752 ft. - 7⅝ @ 11,961 ft. - 5½ @ 12,781 ft.
Continental Oil Co. • Baldwin 1, Clint Shaw, Matagorda Co.	11,612	May, 1937	Dry hole. Shot and on Texas Gulf Coast to go below 11,000 ft., and deepest as far as shot. Drilled most flowing shots. Casing. 20 @ 250 ft. - 13 @ 5460 ft. - 10¾ @ 10,612 ft.
Humble Oil & Refining Co. • Pollard-Duff • Upton Co.	11,327	Drilling	Set 7 inch pipe at 11,327 ft. Testing through perforations. Set 9⅝ @ 5000 ft.
Humble Oil & Refining Co. • Pollard-Duff • Upton Co.	11,134	Dec. 1937	Dry hole. Second Texas test to reach 11,000 ft. Casing. 13¾ @ 260 ft. - 10¾ @ 5920 ft. - 8⅝ @ 10,934 ft.
Harrison & Abercrombie • Copeland • Old Ocean Field, Brazoria Co.	11,130	Drilling	Oil well at 11,130 ft. - 11,140 ft. Testing. Casing.
John J. Manry, Lafford Bros. et al • McDonald • Edmond Co.	10,986	Feb. 1936	Dry hole. Passed 500 bbls. but water, water at bottom. Small oil production for shots after scattering at 10,110 ft. Deepest scattering job in world. Casing. 10¾ @ 258 ft. - 7⅝ @ 8,900 ft.
Harrison & Abercrombie • Bernard 4 • Old Ocean Field, Brazoria Co.	10,775	July 1937	Shut 12,000 ft. oil well at Bass, Producer at 10,686-10,706 ft. - 100 bbls. daily. Casing. 20 @ 20 ft. - 13 @ 1980 ft. - 8⅝ @ 10,775 ft.
Harrison & Abercrombie • Jones 1 • Old Ocean Field, Brazoria Co.	10,751	Sept. 1937	Oil well at 10,690-10,700 ft. 275 bbls. daily. Tenth 10,000 ft. producer for field. Casing. 20 @ 100 ft. - 13 @ 1980 ft. - 8⅝ @ 10,751 ft.
Harrison & Abercrombie • Smith 1 • Old Ocean Field, Brazoria Co.	10,630	Nov. 1937	Oil well at 10,470-10,480 ft. 275 bbls. daily. Flow. 10,600 ft. producer in field. Casing. 20 @ 98 ft. - 13 @ 1960 ft. - 8⅝ @ 10,630 ft.
Superior Oil Producers Co. • Bolin 1 • Bennett prospect, Harris Co.	10,519	Aug. 1937	Box and at 10,519 ft. Casing. 10¾ @ 1980 ft. - 7 @ 9800 ft.
Kennedy Exploration Co. • Cowden 1 • Big City Field, Matagorda Co.	10,497	Drilling	Shut in for 1 week. Casing.
Kennedy Petroleum Corp. • Huff & Oppenheimer & Parnell, Fee Co.	10,471	Drilling	Shut in for 1 week. After plugging back for completion in upper formations. Deepest in South Texas. Casing. 20 @ 20 ft. - 13 @ 200 ft. - 8⅝ @ 10,471 ft. - 5½ @ 9,670 ft.
Shell Petroleum Co. • Stewart 1 • Hitchcock Prospect, Galveston Co.	10,468	Oct. 1936	Dry hole. Texas Gulf Coast first test to reach 10,000 ft. Casing. 13¾ @ 2075 ft. - 8⅝ @ 9,750 ft.
Harrison & Abercrombie • Bernard Rose 1, Old Ocean field, Brazoria Co.	10,437	Dec. 1937	Oil well at 10,400-10,410 ft. 275 bbls. daily. Eighth 10,000 ft. producer in field. Second Texas Gulf Coast test to reach 10,000 ft. Flowing producer of 1000 bbls. Casing. 20 @ 80 ft. - 13 @ 1960 ft. - 7 @ 10,000 ft. - 5½ @ 9,670 ft.
Harrison & Abercrombie • Gohlman 1, Old Ocean Field, Brazoria Co.	10,413	Sept. 1937	Oil well at 10,400-10,410 ft. 275 bbls. daily. Casing.
H. & H. Bernard Fee, Land & Development Co. No. 1	10,401	April 1938	Producing. 20¾ set, cutting @ 10,401 ft.
Harrison & Abercrombie • Bernard 1-A, Old Ocean Field, Brazoria Co.	10,393	Drilling	Directions and was completed at 10,393 ft. Was deepest, encountered at 10,311-10,400 ft. for 250 bbls. daily, after plugging back from 10,400 ft. Casing. 20 @ 100 ft. - 13 @ 2000 ft. - 8⅝ @ 10,393 ft. Deepening.
Gulf Production Corp. • Norris 1 • Willey Co.	10,386	Aug. 1937	Prospect in South Texas Gulf Coast. Completed, originally, at 11,660 ft. Third 10,000 ft. producer. Has abandoned. Casing. 20 @ 136 ft. - 10¾ @ 3455 ft.
Stark Oil Co. • Cobb 8-H, Van West Field, Matagorda Co.	10,362	Drilling	Casing. 10 @ 120 ft. - 7 @ 10,000 ft. - 5½ @ 9,670 ft. - 5½ @ 9,670 ft.
Sun Oil Co. • Fred Robbins 1, Matagorda Co.	10,160	Drilling	Casing.
Sun Oil Co. • J. Ward Estate • La Salle prospect, Jefferson Co.	10,147	Dec. 1937	Abandoned. Shoved dry pay at 10,000 ft. - plugged back, unproductive. Casing. 13 @ 1254 ft. - 10¾ @ 8250 ft. - 7 @ 9961 ft.
United North & South Dev. Co. • Lambert 1, Wilson • Creek Field, Matagorda Co.	10,120	Drilling	Casing. 10¾ @ 9840 ft. Showings in Frio.
Harrison & Abercrombie • Bayou E-10 Tex. Gas Co. • Old Ocean Field, Brazoria Co.	10,120	Drilling	
Gulf Oil Corp. • Morris 10, Orchard Field, Fort Bend Co.	10,095	Abandoned	Casing. 13 @ 1251 ft. - 8⅝ @ 9960 ft. Showings in Frio.
Barry, Bentley & Brewster, Trusty 1, Alpine, Brazoria Co.	10,043		

* Based on information available to us.

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the shop and in the field. Only one oxy-acetylene blowpipe is required for 6-in. pipe and smaller, as a rule, and no additional bending equipment is necessary. The pipe being placed on skids over the ditch, the location of the desired bend is marked. Heat is then applied to a band two or three in. wide on top of the pipe and tapering to zero about half way down the sides. When heated to a bright red the pipe section is rolled over quickly and the skid holding the free end of the pipe is kicked into the ditch or withdrawn. As the other end is held in place on skids the weight of the pipe is usually sufficient to form the wrinkle. The additional weight of a man on the free end is sometimes necessary but generally the man in the ditch is concerned only in limiting the sagging of the pipe to the predetermined bend requirement.

Two blowpipes should be used for heating pipe larger than 6 inches. Naturally the pipe does not bend as readily as the smaller pipe, but, although a bending rig can be used, the regular pipe-handling equipment is generally sufficient.

Stove-Pipe Welding

Increased interest has been manifested during the last year in the so-called "stove-pipe" method of pipe-line welding, a procedure in which each weld is a position weld. Developed late in 1933 near Turnertown, Texas, where it was first used on the construction of an acetylene-welded gas gathering line system, its increasing popularity leads some engineers to predict that it may entirely replace the more orthodox welding procedure on lines of small diameter. It is possible that added experience, together with improved special equipment developed by the economics of the method, may lead to a general usage of stove-piping in laying pipe of any size.

Originally used on short lines stove-piping was used on at least three trunk lines completed within the last two years. A 94-mile, 6-in. oil line over fairly level country from Lyons to Thrall, in Kansas, was constructed for one of the major oil companies by this method. The first long line to be completely electric-welded by the stove-pipe method was constructed for a natural gas company in West Virginia. This 94-mile, 12-in. gas line was laid almost entirely by hand as it traverses extremely rugged, mountainous country. Although it was impossible to use the usual pipe-line construction equipment the line was completed by three gangs in 90 working days.

Another example of the use of this method of pipe-line welding in difficult territory was the construction of the 12-in. gas line from Baytown to Port Arthur, in Texas. This 70-mile line, one of several constructed by this method in the Gulf Coast area last year, was completed by three gangs in 56 calendar days in spite of 25 days of rain that turned that low coastal country into a sea.

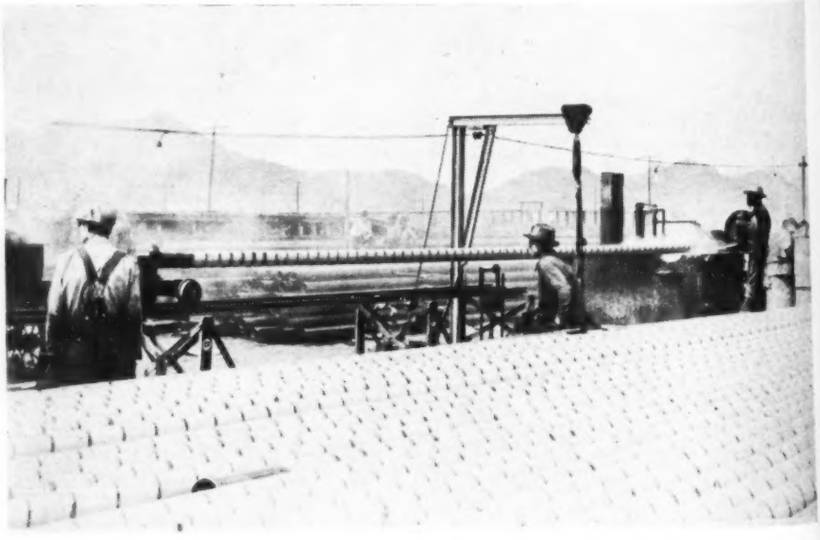
The completion early this year of a 33.4-mile, 6-in. crude oil line from the Buckeye field, Gladwin County, Michigan, to a refinery is a further example of the adoption of this construction method where adverse conditions prevail. Although most of this line was fairly easily constructed, the last ten miles, on the field end of the line, was laid over rough terrain, through mud and heavy timber, in zero temperature.

Originally developed using acetylene welding, stove-piping is now being done extensively using arc-welding, a specially designed "bell-hole" electrode being used. When arc-welding is employed the pipe is aligned continuously on skids over an open ditch and the first or stringer bead is completed by two welders working on opposite sides of the aligned joint. The second and third beads are likewise made in position by additional welders following the line-up gang.

Although the speed of stove-pipe welding may not compare favorably with that of the rolling-weld procedure under favorable laying conditions, under adverse conditions stove-piping is used to excellent advantage. In such circumstances the welding speed may equal or even exceed the speed of welding by rolling-weld procedure, thereby effecting a considerable saving of time and money.

Lowering 24-in pipe into the ditch

(Photo Courtesy The Barrett Company)



Coating and wrapping pipe in the railhead yard of the El Paso Natural Gas Company

(Photo Courtesy The Barrett Company)

Setting up a combined take-off and knock-out unit to pump two wells in the Wilmington field. The counterbalance is moved back and forth along the beam to keep the load in balance. This provides for pumping wells of different loads and allows pumping of one well efficiently counterbalanced when the other is off

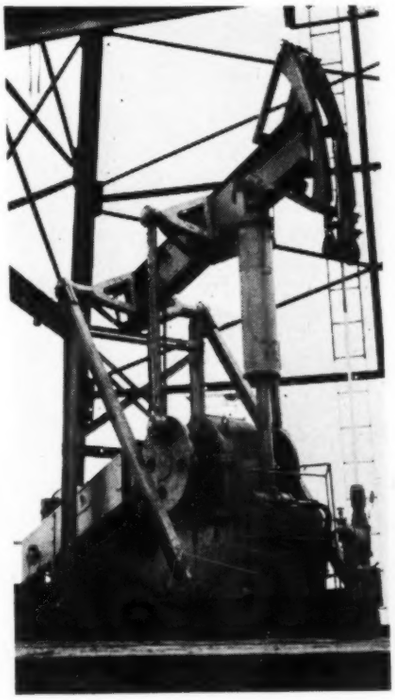
By
WALLACE A. SAWDON
Petroleum Engineer, Los Angeles

Modern Production Practices In California

ALTHOUGH the deep producing fields of California attract the greatest general interest, the more developed areas and isolated wells in the state are the proving-ground for methods and equipment for increasing efficiency and economy of production when the flush period ends and oil must be produced by artificial means. Means of prolonging the period of production by natural flow and gas-lift are most important in deep areas but they offer wide economy and efficiency in any field; and it is by perfection of methods in the general laboratory provided by fields of all depths and conditions that production practice advances. Oil must eventually be lifted by artificial means, however, and whether this means be mechanical or otherwise, the advanced technique of oil production must be developed in this same laboratory, the producing fields.

Particular areas present specific problems. In the Wilmington field the greatest difficulty is caused by the sand produced with the oil. This sand has influenced the rate of production, the selection of producing intervals, and the size of liner perforations; it has shortened the normal life of oil strings, rods, and tubing.

In a discussion of the sand problem, C. J. Dean[1] emphasizes the fact that it is during the heading period of the gas-lift and early pumping stage that the control of sand is most difficult. As means of reducing volume of flow by heads to an amount that will not move the sand, he cites the following: (1) use of a smaller bean; (2) flowing the well from the casing to reduce the surge chamber; (3) use of a packer on the tubing to eliminate the surge chamber; (4) bleeding of casing to a pressure insufficient to blow around the tubing; (5) use of gas-lift to stabilize flow in tubing, and (6) use of a spring-actuated valve or bean to close at a set minimum tubing pressure. The results obtained by gravel-packing wells in this field indicate that this process will be a major factor in the solution of the sand problem.



An air-balanced pumping unit

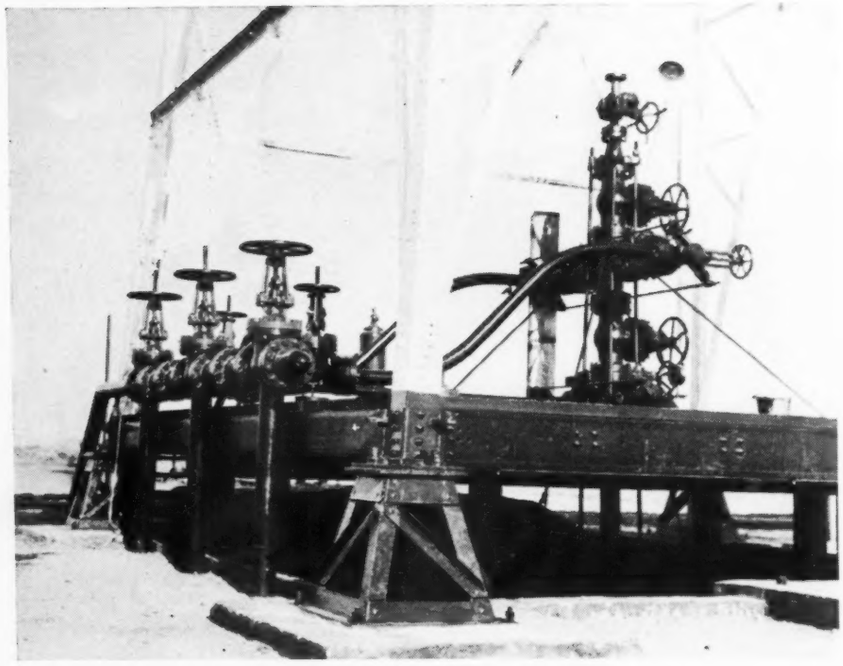
Several wells at Wilmington are producing from two or three zones, the production from each being segregated. This not only separates production of oil of different characteristics but also provides individual control of rate of flow from the different zones. Many of the wells are directionally drilled, either to penetrate the sand below an inaccessible surface location or to produce the oil from each sand through a different hole. The excessive wear of tubing and rods in this field, it has been found, is caused more by the sand than by hole deflection, for a straight hole may cause more wear than a deflected hole.

Gas-Lift Operations

Although gas-lift is used in various fields throughout the state, the greatest number of wells being produced by this method is in the Los Angeles Basin. The procedures followed include injection of gas both through the tubing and through the annular space between tubing and casing. The choice of method depends mainly on the size of liner, size of tubing, and volume of fluid. Intermittent flow is employed in many installations, and patented intermitter devices of various kinds are used to control the operation.

The general method of distributing gas to wells is to use header plants situated at convenient places in the field. Gas from the compressor station, usually at an absorption plant, is transported to the header through a high-pressure and a low-pressure line. The average operating pressure is approximately 250 lb. per sq. in., although some wells are being supplied

[1] "Drilling and Production Problems of the Wilmington Field," by C. J. Dean. Paper presented at the Spring Meeting, Pacific Coast District, A.P.I. Division of Production, Los Angeles, California, April 19, 1938.



Christmas tree and surface connections of Continental Oil Company's No. A-2 K.C.L.

at pressures of 400 to 600 pounds. In some installations extra high pressure is used that is as great as 1000 lb. per sq. inch. This provides for "kicking-off" obstinate wells.

Pressure is controlled at the regulator house, where the gas is distributed to each well at the required pressure. Complete flexibility is provided for pressure and volume of input so that efficient flow can be obtained. The input and output gas are both metered.

Bottom-Hole Pressures

The most effective use of bottom-hole pressure data is made when an entire pool is under control of one operating organization. Most of the large operators having a sufficiently large block of acreage in such fields as Kettleman Hills, some of the Coastal fields, Dominguez, Coyote, and Belridge, make periodic bottom-hole pressure measurements and on the basis of the data obtained study the distribution of production and the broad aspect of reservoir control. By use of bottom-hole pressure records, the approach of edge water can also be controlled to a considerable extent. The data are used for individual well studies and for field study. In many areas where acreage holdings are small, bottom-hole pressures are sometimes measured for study of the individual well, although broad control of reservoir conditions cannot be planned under too restricted a scope of operation. Some companies, however, are exchanging information on bottom-hole pressures and this coöperation not only aids in the efficient production of the pool but also makes it more desirable for individual companies to make periodic measurements of bottom-hole pressure for the production control of individual wells.

In a recent paper on bottom-hole pressures[2] it was stated that inasmuch as the oil is produced as the result of difference in pressure between the producing formation and the bottom of the hole, the pressures are basic and any operating procedure depends on these pressures for its success. As bottom-hole pressure determinations are an important factor in determining the reservoir condition, the data they provide will assist in making an accurate estimate in the early life of the field concerning when oil must be produced by artificial lift and what conditions must be met with the equipment to be installed.

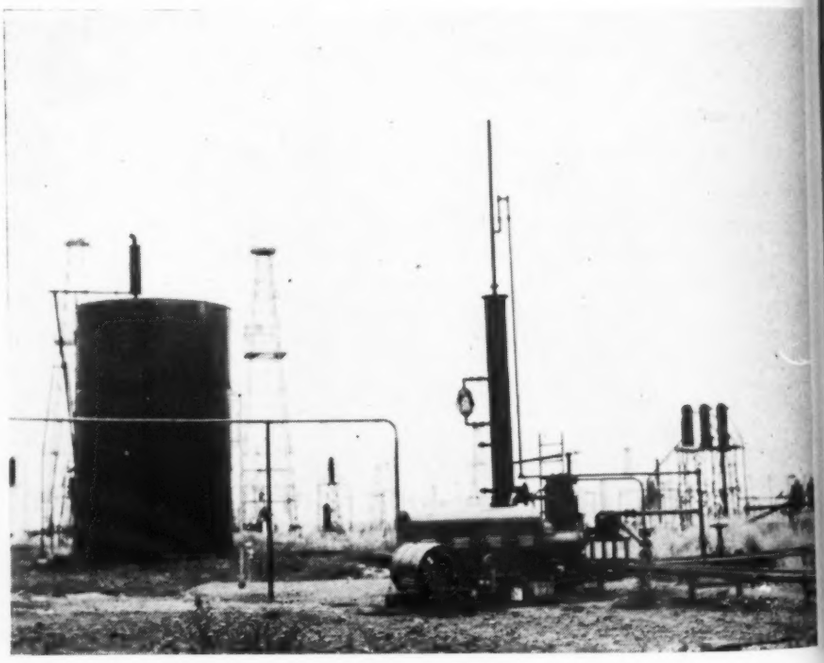
In pumping wells the bottom-hole pressure measurements also provide data that will disclose whether the amount of fluid being produced is limited by the ability of the well to produce or by the ability of the equipment to lift the available fluid. As the height of the fluid level in pumping wells is an index of the pressure on the sand and of the differential pressure across the face of the sand, the determination of the fluid level provides information that can be used for controlling production and checking equipment in individual wells.

Two devices for the determination of fluid level in pumping wells are being used in California at the present time.[3, 4] An advantage of these devices

[2] "Bottom-Hole Pressures in Current Oil Well Operations," by C. V. Millikan. Paper presented at Mid-Year Meeting, American Petroleum Institute, Wichita, Kansas, May 24, 1938.

[3] "The Depthograph," by C. P. Walker. Paper presented at meeting of Southern California Petroleum Section of the A.I.M.E., Los Angeles, California, October, 1936.

[4] "Fluid Level as a Guide to Pumping Efficiency," *The Petroleum Engineer*, January, 1938.



The "gang" pump or multiple hydraulic pump, operating six wells in the Dominguez field

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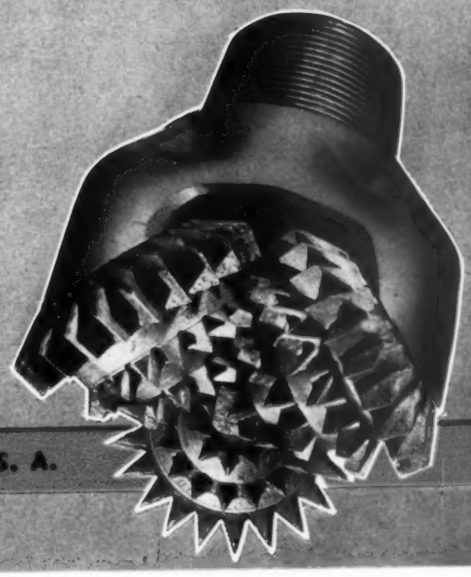

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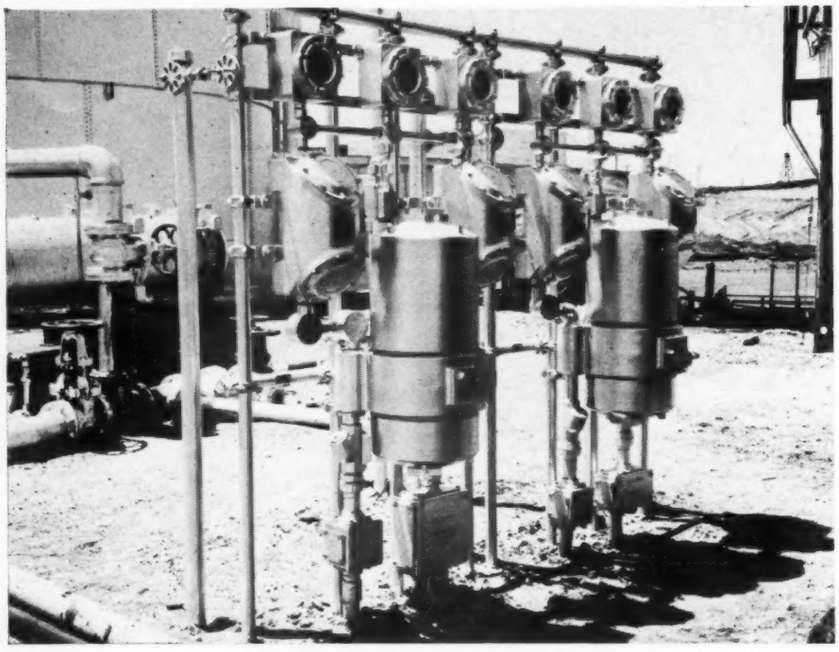

Explosion-proof equipment for automatic electrical control at electrical dehydrator installation

is that they permit making the fluid level measurement without shutting-down the pump or interfering with production in any way. Although this process measures within very close limits the depth of fluid and also the height of the fluid column during pumping operations, it does not measure the factors affecting pressures. Some operators still use pressure bombs exclusively in pumping wells; others using fluid level measurements sometimes take bottom-hole pressures to augment the data provided by the more frequent determinations of fluid level.

Pumping

More than 90 percent of all the active producing wells in California being on the pump, the importance of pumping equipment and the necessity for efficient and economical pumping practice have led to many experimental installations that have resulted in the development of new equipment and methods to the general benefit of the industry. One of these is a new all-electric submersible pump that has already provided some interesting performance data at Elk Hills, where several units of this type equipment have been installed. All types of pumping units are in use in the many fields of the state; the plunger lift and hydraulic pumping installations continue the lead in the rodless pumping devices that have become established by several years of successful operation.

The latest development in hydraulic pump application is a multiple set-up called a "gang" pump by men in the field. One installation of this equipment at Dominguez, shown in an accompanying illustration, is pumping six wells. The total production from these wells is 535 bbl. per day, individual well production ranging from 34 to 188 barrels. The principle of operation is the same as that of the hydraulic pump, which has been fully described in many articles,[5] although the surface installation appears rather different from the units widely known.

The power oil is pumped by a triplex unit direct-driven by a 40-hp. electric motor totally enclosed in a hood. All production from the six wells goes to a boiler and is heated to approximately 160 deg. fahrenheit. The heated oil then goes to the 750-bbl. settling tank (shown at the left in the illustration) where the water settles and is bled-off automatically. The oil enters the tank at the top and flows downward through the center. As the water settles the clean oil rises through an outer chamber.

Only clean oil goes to the power-oil supply, where the level is maintained by a kidney valve that keeps the oil at the proper level to supply the triplex pump. The power oil is pumped through a manifold line from which a lead runs to each well. At each well there is a metering valve to control the amount of oil and regulate the strokes per minute of each pump.

[5] "Hydraulic Power Applied to Oil Well Pumping," by C. J. Coberly. Paper presented at Annual Meeting, American Petroleum Institute, Los Angeles, California, November 13, 1935.

Constant pressure is maintained on the manifold line by a pressure-control valve and this pressure is kept slightly above the highest required by any well. When any well goes off, the pressure-control valve maintains the pressure on the other wells and these continue pumping without being affected by the shutdown of any other well or wells. The height of the intake is regulated by the kidney valve. Should this fail to function there comes into operation a vacuum-controlled switch on the pump supplying oil to the triplex pump. Any number of wells can be pumped from the one installation providing sufficient power is supplied by the triplex pump.

An important feature of this installation is that all oil is clean when it leaves the tank. A treating chemical is introduced at the intake of the triplex pump and mixes with the power oil. The already clean power-oil carries the chemical mixture into the hole and the oil produced by the well is thus treated before being heated and sent to the settling tank. No further treatment of the oil is necessary.

Treating

The latest development in electrical dehydration is an installation of two units in the tank farm of Standard Oil Company's refinery at El Segundo. This dehydrating plant is equipped with explosion-proof electrical control equipment to provide safety in automatic control when operating at a refinery. These units are double-transformer CF type and treat gas-lift production of 2500 bbl. per day from the El Segundo field.

For chemical treatment of emulsions in the Wilmington field some operators have installed a high treating tank of recent design. The cut oil mixed with the chemical reagent is pumped into this tank where the sand and some of the water produced with the oil settle. From the tank the partly cleaned oil flows to a settling tank where the rest of the water separates. The clean oil then goes to field storage.

Glass filters are being used in connection with chemical treatment in some of the California fields. The cut oil is heated and chemically treated and then put through the filter, which consists of finely broken glass.

Modern Cable-Tool Drilling Practices

By C. ERIK CAPITO

ALTHOUGH cable-tool drilling has become obsolete in many parts of the world, it still is used for many purposes and in many places. In those areas where pressures are low and water strata few, it is possible by the use of cable tools to complete a well successfully that otherwise might be mudded-off by the rotary method.

Modern cable-tool drilling demands an all-steel rig and derrick. Not much need be said of the derrick; one 84 to 94 ft. in height and having a 20- to 24-ft. base is usually quite sufficient for all cable-tool work. The door is placed to the right of the rig and on many derricks an extra door is provided on the rig side to give access to the catwalk. On the left of the rig and opposite the main door many operators install an extra cable drum of the rotary pattern and another engine, the objects being to use both ends of the casing line and to facilitate work on a heavy string of casing.

On the modern standard rig (Fig. 1) the sand reel and calf wheel, or casing spool, are driven by flat-link chains on sprockets, which are set in motion by dog clutches on the band-wheel shaft. The sand reel has in addition a plate clutch on its own shaft, which is operated by a lever situated in front of the calf wheel. The brake on the sand reel is operated by a reverse motion of the same lever; this lever when in its central (upright) position allows the reel to run free for lowering the bailer. For drilling deep wells the bull-wheel is usually operated by two tug ropes. The temper screw generally allows about six ft. of drilling to be done before resetting the clamp on the drilling cable.

Drilling cables are usually made of an alloy steel having a tensile strength of 90 to 110 tons per sq. in., and constructed of six strands of 19 wires left-hand lay, although some operators use lines of right-hand lay construction. The diameter of the cables for drilling is usually ⅞ inch. Casing and sand lines are almost invariably right-hand lay, the former being ¾-in. to 1-in. diameter and the latter ½-in. or ⅝-inch.

Drilling and fishing jars are now almost all made of weldless alloy steel. Sinkers are similarly made, and although slightly more expensive than the welded type are safer and less likely to fracture. Drilling bits, whether straight or eccentric, are made long for ease in fishing should the pin break or become unscrewed. The length may be as great as seven ft. for a 15-in. bit and 3 ft. 6 in. for a 4-in. bit. When one of the larger size bits becomes too short it is knocked-down to the next smaller size.

The motive power used for cable-tool drilling varies with the locality and conditions. Steam is the most flexible and where used a single-cylinder engine 10 in. by 12 in. or 12 in. by 12 in. is usually sufficient for the deepest cable-tool well, especially now that boiler pressures exceeding 250 lb. per

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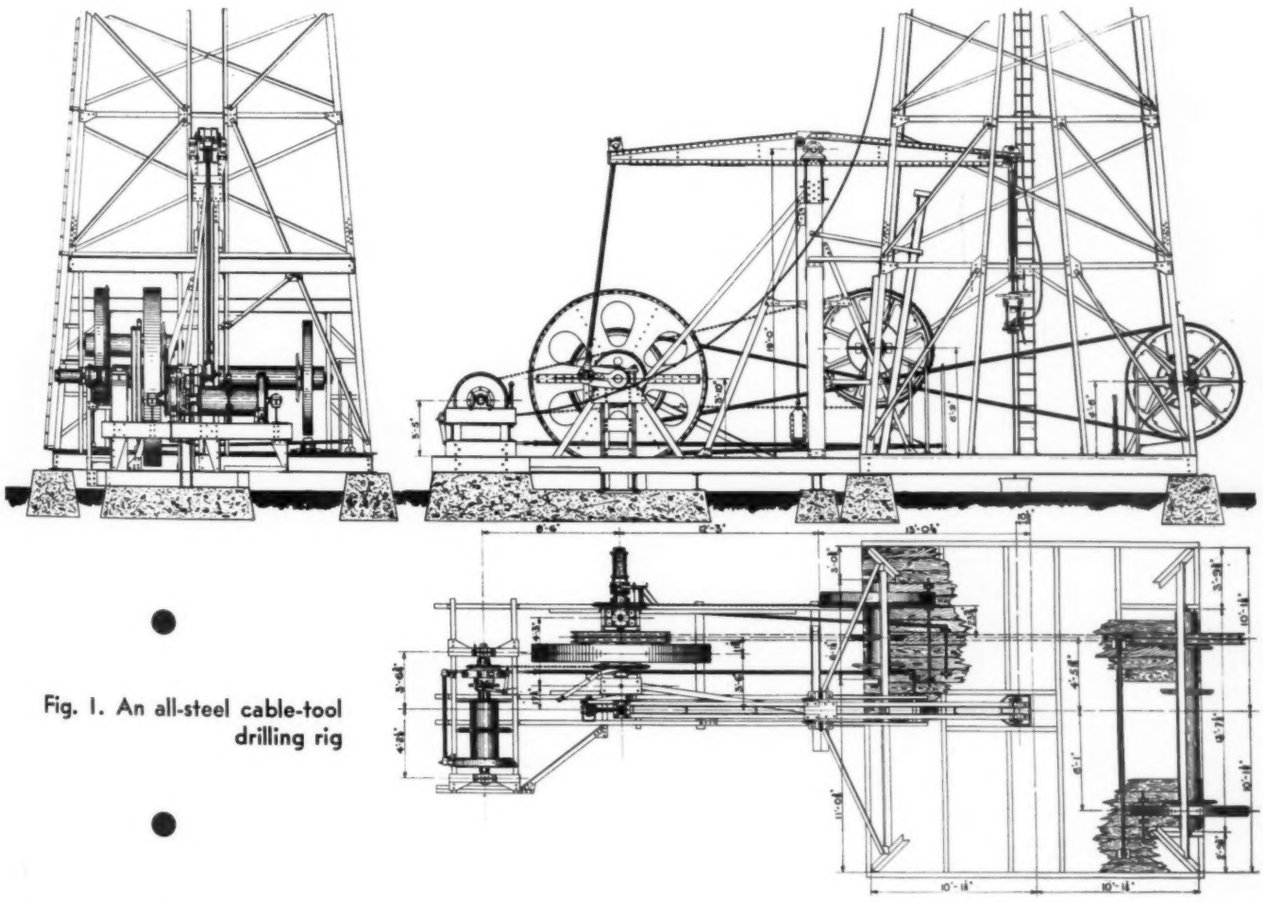

Fig. 1. An all-steel cable-tool drilling rig

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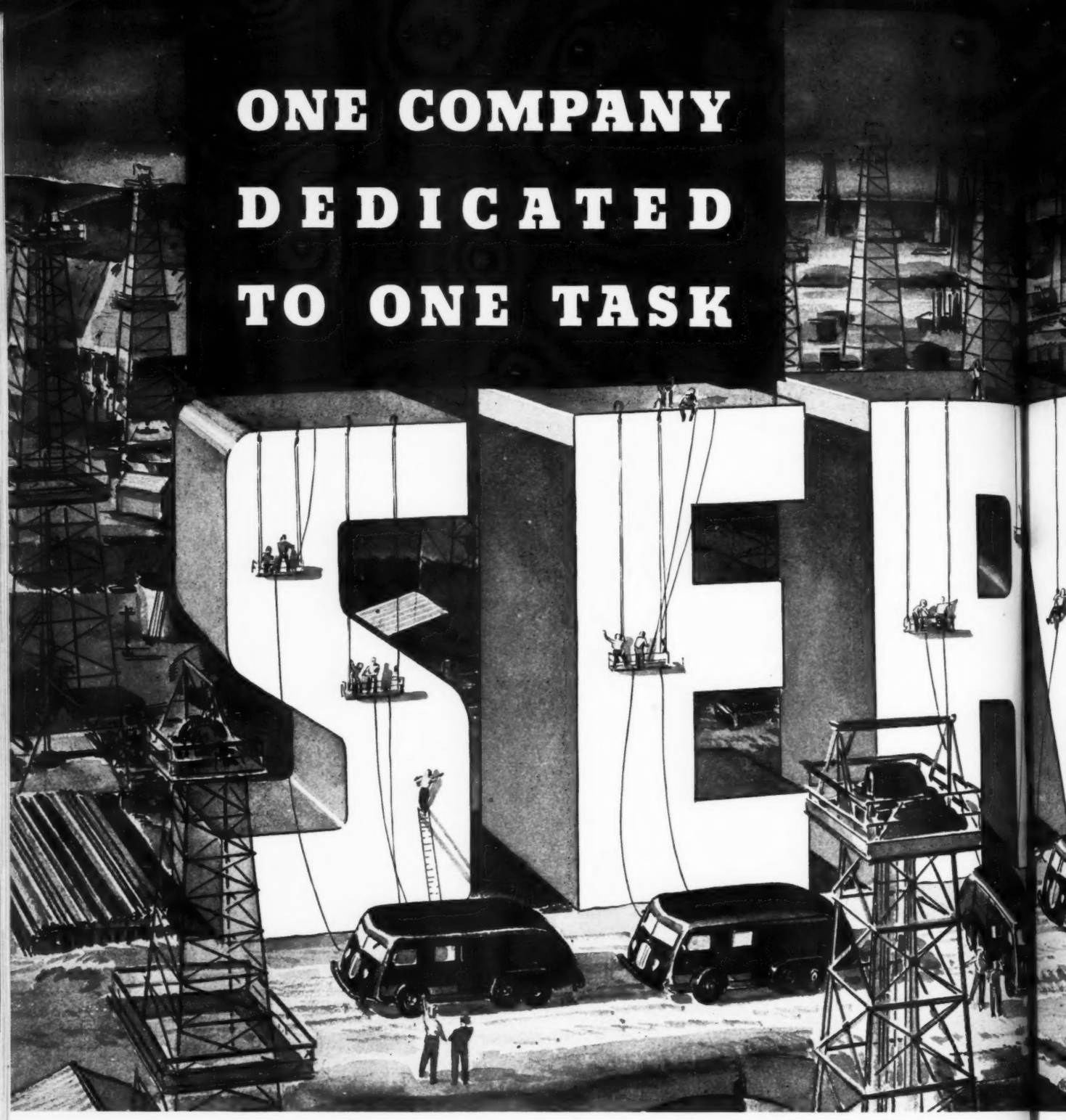

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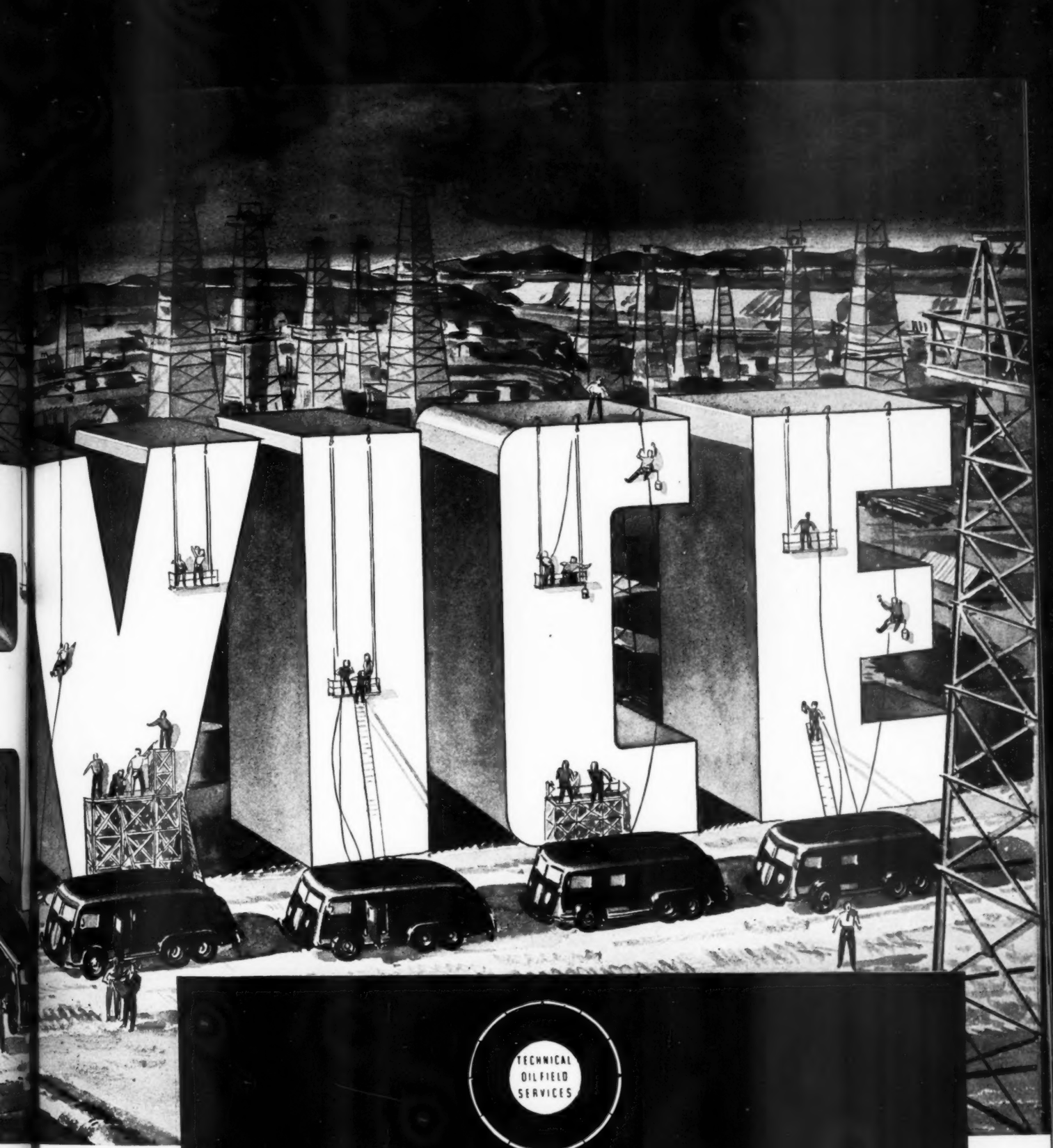

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(*Continued from Page 87*)

sq. in. are used. Where water is scarce or bad or where fuel must be carried a long distance internal combustion engines often are used. They are gasoline- or kerosene-driven, of about 120 b.hp., and have four or six cylinders. In other places, where electric power is available and cheap, many operators use electric motors. If one motor is used, 75 b.hp. is the common size, but some operators use two 35- to 40-b.hp. motors, either or both of which can be coupled to the main drive by dog clutches. One motor is used for drilling and both for pulling-out, bailing, or running casing.

When erecting standard rigs it is usual to build these and the derricks on concrete foundations. Where possible the contour of the ground is utilized to reduce the amount of concrete required. The size of derrick piers depends on ground conditions. They are usually made slightly tapered, and the pressure from the derrick legs is distributed over the top of the piers by a steel plate or channels.

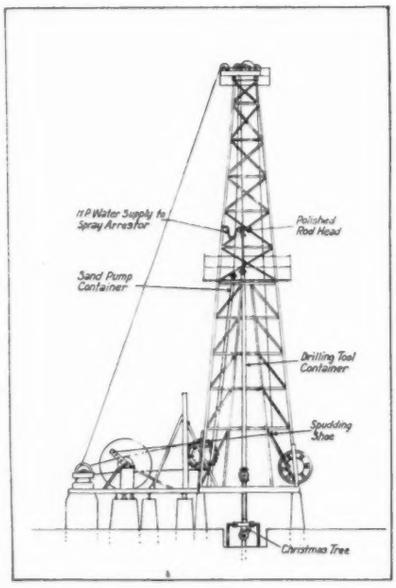
In order to accommodate blowout preventers, flowheads, etc., below the derrick floor, often it is necessary to have a cellar around the casing. This is excavated to the required depth and about 8 to 12 ft. in diameter, the circumference of the cellar being walled with concrete or masonry, and the floor being of reinforced concrete to take the casing clamps. Access to this cellar is best made by one or more ramps, which should be in line with the prevailing wind so that the cellar will be kept clear of gas. This is especially necessary where hydrogen sulphide or other poisonous gas is likely to be encountered. The height between the floors of the derrick and cellar varies with the size of casing and type of blowout preventers and Christmas tree to be used, and is generally 10 to 14 feet. If it is desirable to run casing with the clamps on the derrick floor, and often it is more convenient to do this, it is usually necessary to support the derrick floor by struts of old casing or I-beams from the cellar floor. Often these strengtheners are included when the derrick is erected. They should then be so arranged that they do not cramp the center of the cellar and should leave ample room for access to the flowhead and valve connections.

Drilling, where possible, is carried on in dry hole. Water for drilling purposes should always be dumped with a bailer and never allowed to drop from the surface as caving is sure to occur. When a water stratum is struck the usual practice is to drill past the horizon and then to set temporarily a string of casing to exclude the water, the hole being bailed dry before proceeding further. Operators who use eccentric bits then drill for six ft. below the casing shoe using a straight bit and then change to the eccentric bit, and it is then necessary only to ream this six ft. before carrying the casing further. In many formations the use of the eccentric bit saves considerable time even though on the whole it is usually more difficult to make as great a footage per tour using this type bit.

In wildcat wells, or in areas where operators are not sure where oil will be found, it is often desirable to drill ahead with a pilot hole after cementing or temporarily setting a string of casing. Such pilot holes are usually about 4 in. in diameter when carrying 8⅝-in. or larger casing. When starting these pilot holes it is necessary that they be drilled concentrically with the main hole. This is assured by fixing a wing guide above the bit and often another between the sinker and jars. The lower is removed as soon as the bit is buried and the upper when the sinker is nearly buried. These pilot holes are much easier to plug than is the regular size hole if a strong show of oil, gas, or water is struck before surface arrangements to control the flow are completed.

If, after drilling the pilot hole some distance ahead, nothing is found and evidence shows that the producing horizon is still some distance ahead, the pilot hole can then be enlarged to full size. To insure following the pilot hole with the full-sized hole, often a straight bit is dressed like a rotary fishtail bit. When drilling through any thickness of salt it is advisable to ream the hole with the reamer dogs dressed-out extra wide. This makes it more difficult for the salt crystals to build out and seize the casing, as so often happens otherwise.

Fig. 2. Diagrammatic sketch showing arrangement for drilling-in a well under high pressure with cable tools and through containers



While drilling, samples of the cuttings brought up by the bailer should be kept for geological purposes. They should be dried naturally, put into a container (either a can or bag) when dry, and the depth from which they have come carefully marked on the container.

With regard to fishing tools, slip sockets with or without bowls and fitted with dogs to catch the various diameters of drilling tools in use seem to be the most useful and they can be made to let go if the lost tool cannot be pulled. For special jobs often it is necessary to use special tools designed on the spot. A wise operator, however, will always have a rope spear and at least one string of fishing tools suited to his drilling tools standing in the derrick already coupled with fishing jars, sinker, and necessary subs so that the fishing tools can be used with a minimum of delay should a 'fish' occur, as often it is much easier to recover a lost tool if it is fished for at once.

The various types of cementing, single or double plug, single or multiple stage, can all be used just as easily with cable tools as with rotary except that the follow-up mud has to be made specially. This, however, can be prepared ahead of time. Where operators have the required amount of 2-in. or 3-in. tubing the tubing method can be used and it requires much less follow-up mud. When drilling out the cement plugs the straight bits should be dressed rounded at the sides to prevent drilling a hole through the casing wall.

Safety Measures

The following safety measures are not necessarily confined to cable-tool drilling and many of them can be, and are, utilized on rotary work.

After the site of the well has been located the first thing an operator should do is to ascertain the direction of the prevailing wind both during the day and night; the rig should then be so placed that the normal wind will blow clear through the derrick and not blow gas from the well into the driller's face when he is standing at the normal controls, i.e., the bull-wheel brake should be on the windward side of the well. Next a suitable site for the boilers should be found on the windward side of the well and not less than 100 ft. from it and preferably

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about 300 ft., depending on the size of the well expected. All boilers should be fitted with a steam snuffer to cool quickly the target and other brickwork if gas is struck and the wind happens to blow in the wrong direction, or if there is a dead calm. The farther the boilers are from the well, the less is the importance of this precaution, but snuffers are inexpensive and well worth applying. If water at high pressure is available, a water snuffer can be used, but steam is more efficient. Where thought necessary these snuffers can be controlled by the driller by means of a cable from the well. The boilers should be so situated that the fireman can see what is going on at the well from his normal firing position, and boiler-feed pumps, injectors, and blow-down cock handles should be so placed that the fireman is not hidden from the well while working on them.

Internal combustion engines should have their exhaust outlets made spark-proof, either by water injection or by taking the exhaust gases to a safe distance from the well and burying the end of the lengthened exhaust pipe in loose rubble. Such extra length of pipe can be made of old casing or line pipe provided the joint between it and the exhaust pipe from the engine is made tight. Care must also be taken to see that the magneto or coil is made "explosion proof," and spark plugs can be wrapped with insulating tape to prevent a spark from the ends of the high-tension wires. Electric motors, their switches and controllers, should be "explosion proof" and generally comply with the regulations for electricity mentioned below.

On the well itself the cellar, as mentioned, should be so arranged that the prevailing wind will clear it of gas. A pump should be provided to clear the cellar of any oil or water. A life line must be provided from the normal working position in the derrick and taken out on the windward side. This rope should be of manila. If a wire-line life line is used a suitable carrier must be provided so that men do not have to put their hands on the wire line. Care must be taken that no loose tools, bolts or nuts, or planks are left in the derrick. While a man is working in the derrick he should be made to wear a life belt with a line attached to some fixed part of the derrick. Any tools should be tied either to him or to some fixed part of the derrick. It is advisable to have a chemical fire extinguisher (say 10- to 20-gal. capacity) or at any rate some buckets of sand handy. Although such would be useless if a blowout occurred, it is often possible to stop a small fire from spreading if some fire-fighting appliance is immediately at hand. If workshops are not available, bit dressing should be done at or near the boilers. When working in a gas-laden atmosphere or near oil or gas, all brake bands should be sprayed with water to prevent sparks. It is safest to use bronze-headed hammers. Smoking, the use of naked lights, and even the carrying of matches in an oilfield or near a well that is likely to strike oil momentarily should be prohibited. It is so easy for anyone to strike a match without thinking of the danger.

Electric fittings should comply with regulations for electricity in fiery mines, i.e., switches and lamp fittings should be "explosion proof" and plugs should be of the type that the male member cannot be pulled out while the current is on. Wiring should be enclosed either in conduit or in heavy cable. There should be a master switch close to the driller's normal working position to control the derrick lights and another switch about 100 ft. from the well on the windward side to control all lights.

Many operators remove the electric fittings before drilling-in a well and install floodlights at a safe distance from the derrick. These also should be "explosion proof". The safest plan is, of course, not to work at night when expecting oil momentarily, but to work during daylight only. The flood lights should be installed in case an accident occurs at dusk and it is necessary to work until the trouble is rectified.

Before reaching the oil zone it is always safest to have at least one string of casing cemented to surface. Each string thus cemented should be tested hydraulically to at least 50 percent above the oil or gas pressure expected in the well, remembering that a slight leak may, and probably will, develop into a bad one when subjected to the oil or gas pressure.

A master gate valve should be fitted to the last string of casing before starting to drill-in or to drill ahead in unknown territory and this valve should be tested to the same pressure as the casing. A pressure gauge should be fitted to the underside of the valve so that should it be necessary to close the valve the pressure in the casing can always be watched. Above this valve a full-sized flowhead or Christmas tree should be fitted with side flow valves, beans, etc., for controlling any flow from the well. Above this Christmas tree an oil-saver can be fitted and drilling continued through this oil-saver. Some operators drill-in through containers (Fig. 2). In this case a second full-size master gate valve is fitted to the top of the flowhead, but a flanged valve is used to which the container (usually made of 40 or 50 ft. of the same size casing as that in which drilling is being done) is flange-connected. The top of the container is fitted with a stuffing box and polished rod, which itself has a second stuffing box that can be clamped to the drill cable. In case of a flow the tools can be drawn into the container, the top master gate shut, and no oil lost. When using a container the beam is discarded and the well spudded-in. As drilling proceeds the polished rod must be moved up the drill cable and reclamped. The stuffing box is fitted with a connection to enable water under pressure to be pumped into it to prevent oil coming out. This makes a much cleaner job after oil is struck. A second container is used for the bailer, though once a flow of oil is struck the cuttings usually come up with the oil. While using containers it is best to fit a steel plate under the drilling and sand line sheaves on the crown block to prevent the polished rod from being carried around, throwing the rope off the sheaves. Using these containers a big well can be drilled-in and safely completed without any sign of oil on the derrick floor. They are likewise very useful for the same reason if the well, in its after-life, needs to be swabbed.

All valves on the Christmas tree and especially the lower master gate should be fitted with long-distance control handles. These are best made of 3-in. tubing that has the collars pinned and welded to prevent unscrewing. Knuckle joints must be fitted where necessary and the tubing supported at intervals on rough bearings. The control handles are taken out to the windward side of the derrick and may be as much as 80 ft. long. The control point should be beyond the reach of any spray from the well.

If hydrogen sulphide or other poisonous gas is likely to be struck, gas masks should be provided for the whole crew, who must be instructed in their use. The masks should be kept on the windward side of the derrick and care must be taken to see that the chemicals are in good order. Even for a non-poisonous gas it is well to have one or two gas masks handy.

In *known* low-pressure areas many of the above safety measures would not be necessary. Drilling through containers, remote controls for valves, and even the provision of a Christmas tree might not be required, but with regard to other measures, which might seem unnecessary, it must be remembered that most cost very little compared with damages that might be assessed against the operator should something go wrong.

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"I find that we have to agree with you regarding the benefits derived from oil-cooled pistons, in eliminating excessive wear and ring trouble.

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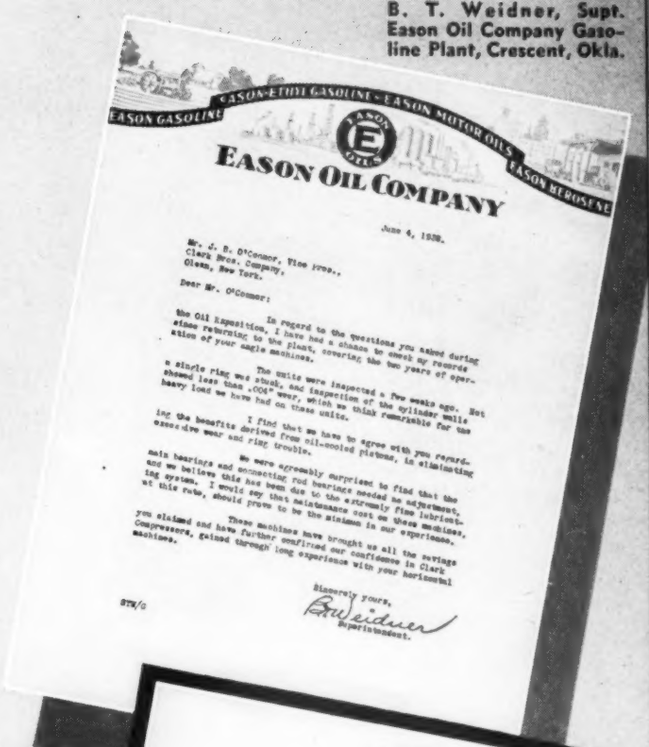
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I find that we have to agree with you regarding the benefits derived from oil-cooled pistons, in eliminating excessive wear and ring trouble.

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These machines have brought us all the savings you claimed and have further confirmed our confidence in Clark Compressors, gained through long experience with your horizontal machines.

Sincerely yours,
B. T. Weidner
Superintendent.

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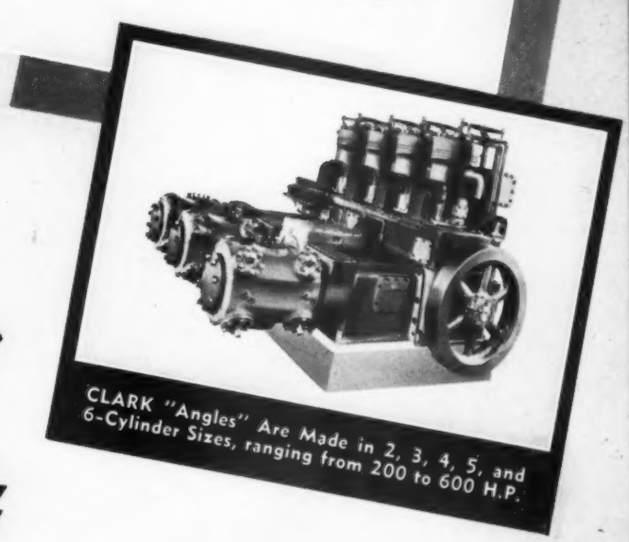

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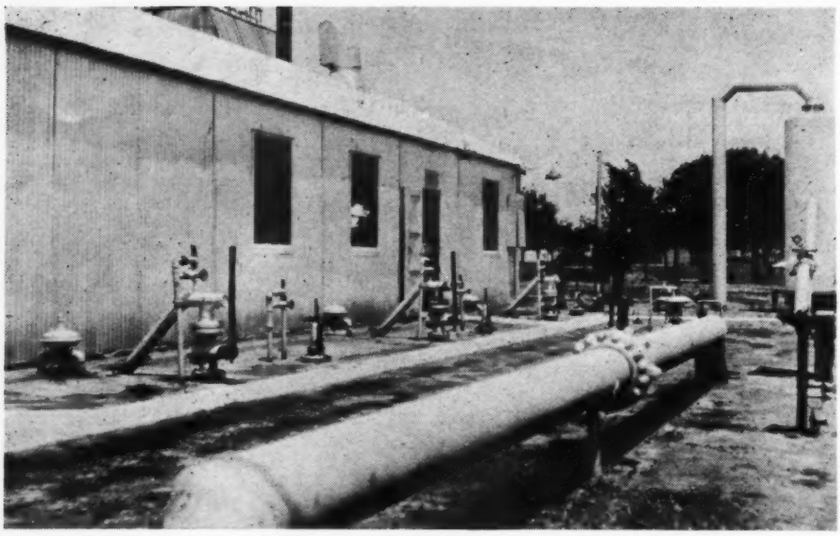

Gas-lift plant in the Fair Grounds area, Oklahoma City

By
S. F. SHAW
Consulting Engineer

Progress and Trends in Gas-Lift Operation

THE methods of gas-lift now in use are becoming more diversified, depending on the conditions under which oil is being produced. Every effort is being exerted during the present period of severely restricted production to maintain use of the natural-flow phase of gas-lift because of the necessity for avoiding, or delaying, the outlay of capital employed for installing artificial-lifting equipment.

Many of the new fields are severely restricted in production, and reservoir pressures are declining slowly, under which condition natural flow can be maintained for a longer period of time than were these fields produced at maximum capacity.

Natural Flowing Wells

To produce only the required allowables, naturally flowing wells are operated either continuously at a very low rate of production, or they are flowed intermittently for short periods. Continuous flow at greatly restricted rates has its advantages, as well as its disadvantages. Continuity of operations, regular supply of gas for gasoline plants and for lease operations, and gradual decline of reservoir pressures are among the advantages, whereas in some instances freezing of chokes, deposition of paraffin, and higher labor cost are among the disadvantages.

Many wells on natural flow are so close to the dividing line between natural and artificial flow that they are difficult to start on production after they have been closed-in for a time. In many wells, the use of "kick-off" valves, or booster collars, solves this problem for a considerable length of time. The conditions in some wells are such that these "kick-off" valves alone are sufficient to cause a well to start flowing on its own gas when opened, whereas in other wells the addition of outside gas is necessary to start the flow.

Among the makes of "kick-off" valves in use for this purpose are the Bryan, G.P.I. (Greenlee-Taylor), Merla, P & T, and the Williamson valves. P & T valves have been employed in the Turner Valley field, Canada, for bringing in wells by means of gas-lift at pressures that are not excessive.

When naturally flowing wells are severely restricted by back-pressure, gas-oil ratios may be either higher or lower than at much higher rates of flow. Often high back-pressure tends to raise the gravity of the oil one or two deg. A.P.I., which results in a somewhat higher price for the oil if the price is based on gravity.

Artificial Gas-Lift Flow

The methods of artificial gas-lift flow employed at this time are as follows:

1. Continuous, or straight, gas-lift.
2. Combination gas-lift.
3. Intermittent gas-lift.

Continuous flow is employed when reservoir pressures are high and when large production is desired, especially when the quantity of formation gas remains a substantial percentage of the total quantity of gas required to lift the oil. Continuous flow can also be employed for lifting small daily allowables by flowing through the tubing.

Continuous flow has been employed during the last year for completing wells in California at Dominguez, Kettleman Hills, Midway-Sunset, El Segundo, Seal Beach, Shiells Canyon, Ventura Avenue, and various other California fields.

Straight gas-lift has been employed in Oklahoma in the Crescent, Moore, Oklahoma City, and other fields. In Texas it has been employed in the Corpus Christi, East Texas, Refugio, Rodessa, Saxet, and other fields. In Louisiana, gas-lift has been employed in the Rodessa field.

"Kick-off" valves are employed in Corpus Christi, East Texas, Refugio, Saxet, several fields in Duval and Webb counties, and several fields in West Texas for starting wells on continuous flow.

Kettleman Hills in California is gradually reaching the stage when gas-lift will become necessary to lift oil from most of these deep wells. If it becomes necessary to lift large quantities of fluid in this field, the centrifugal-pump-gas-lift combination method may become advantageous.

The Moore field in Oklahoma is entering the gas-lift stage of production. The wells are deep, completed with comparatively small casing, and produce considerable water; therefore, a serious problem is faced in the lifting of production from these wells.

Practically all wells producing from the Wilcox zone of the Oklahoma City field have been operated on gas-lift at one time or another, but they are now nearly all removed from this method, as the reservoir pressure has declined to a pressure between 10 and 50 pounds. A well on continuous gas-lift having 31 lb. flowing pressure produced 200 bbl. per day through 9⅝-in. casing, but it was found that under this low-pressure condition the Reda pump, the Kobe hydraulic pump, and the beam pump could lift a larger

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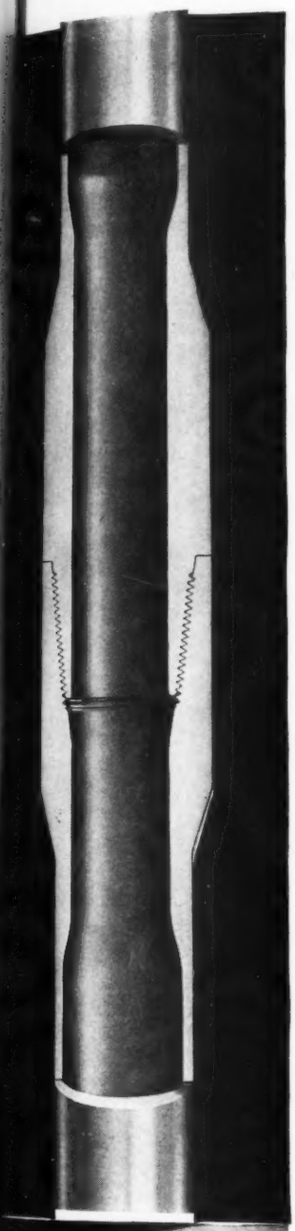

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quantity of oil, consequently practically all gas-lift installations in the Wilcox sand have been discontinued; however, in the Fair Grounds area of the Oklahoma City field, and in the older Simpson sands, continuous gas-lift is yet being operated to advantage, and wells are producing 200 to 2000 bbl. of fluid per day. The reservoir pressure in this area varies from perhaps 300 to 1000 lb. per sq. inch.

"Kick-off" valves are employed in the Cresent, Lucien, and Oklahoma City fields for starting some of the high-pressure wells on continuous gas-lift.

Continuous gas-lift flow is employed largely for producing wells in the Corpus Christi, Refugio, and Saxet fields. In Corpus Christi, it has been found that wells making two to four percent oil can be profitably operated on straight gas-lift where other methods have failed, and fluid containing ten percent oil can be considered as "bonanza" oil. High fluid levels, low quantity of input gas required per bbl. of fluid, low price for input gas, low treatment cost, and low cost for water disposal are important factors contributing to the possibilities for making the operations profitable at Corpus Christi although high percentages of water are produced.

Gas-Lift Wells in the East Texas Field

Date	*Wells Not Making Water*	*Wells Making Water*	*Total Wells*
October, 1936	222	63	285
January, 1937	243	71	314
April, 1937	286	72	358
October, 1937	307	123	430
January, 1938	351	97	448
April, 1938	343	121	464

An instance may be cited of a well in the Corpus Christi field that is producing about 1800 bbl. of liquid, of which two percent, or 36 bbl., is oil. The quantity of input gas at 400-lb. pressure is approximately 690 cu. ft. per bbl. of liquid, or 34,500 cu. ft. per bbl. of oil. The pressure of the intake gas from near-by wells is about 150 lb. and is increased to 450 lb. by a small compressor plant, under which condition the gas can be compressed at an operating cost of approximately ½ cent per M. cu. ft., thus making the lifting cost of oil 17½ cents for the gas consumed. So long as these favorable conditions prevail, it would seem that liquid containing one to two percent oil, or 98 to 99 percent water, could be lifted at an operating profit; however, wells would never pay out if they had to start with an oil content as low as one or two percent, but would show an operating profit if capital outlay has already been returned from the production in the early life of the wells.

The East Texas field probably has more wells now on gas-lift than any other field in the world. Because of the very small allowables in this field, about 20 bbl. per well per day, even the large number of wells on gas-lift does not make the quantity of oil produced comparable to that of other gas-lift areas. Owing to the low allowables and high fluid levels, the cost of equipping wells with gas-lift in East Texas is low, ranging from $500 to $1000 per well where several wells can be operated from the same plant.

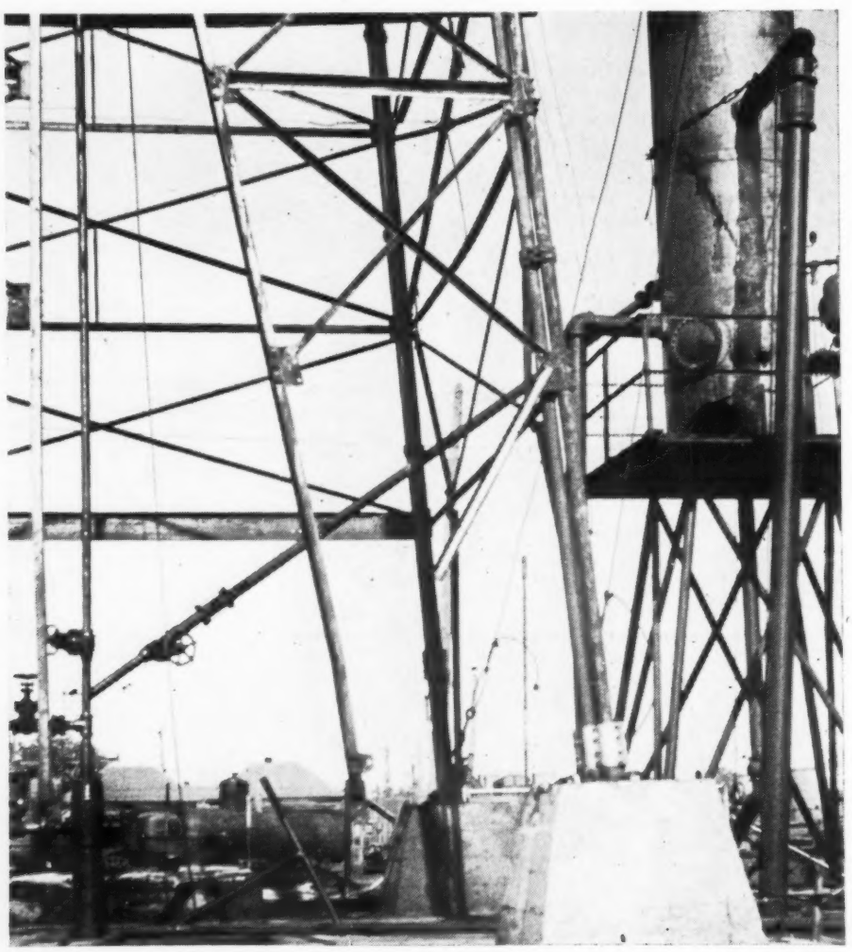
The growth of gas-lift operations in the East Texas field is shown in the table at the top of this page.

Reservoir pressure in the Rodessa field, Louisiana, has declined, and water has made its appearance, consequently there has been a noticeable drift toward the use of gas-lift in this field. "At present there are about 91 wells operating under some form of artificial lift, of which about one-half are pumping, and the others on gas-lift of one type or another. The inability to make daily granted production has prompted the growing use of gas-lift."

Combination Gas-Lift

The Reda-pump-gas-lift combination method has been an outstanding accomplishment during the last two years in the Oklahoma City field. Owing to the very low fluid levels now existing, many of the installations of this combination method have been discontinued here, although there are yet instances in this field of wells on combination method yielding 1000 to 2500 bbl. of oil per day, reservoir pressure being 20 to 40 lb. per sq. inch.

The Kobe-gas-lift combination method has demonstrated possibilities of considerable merit, but present low allowables have tended to retard further development of the method at this time.



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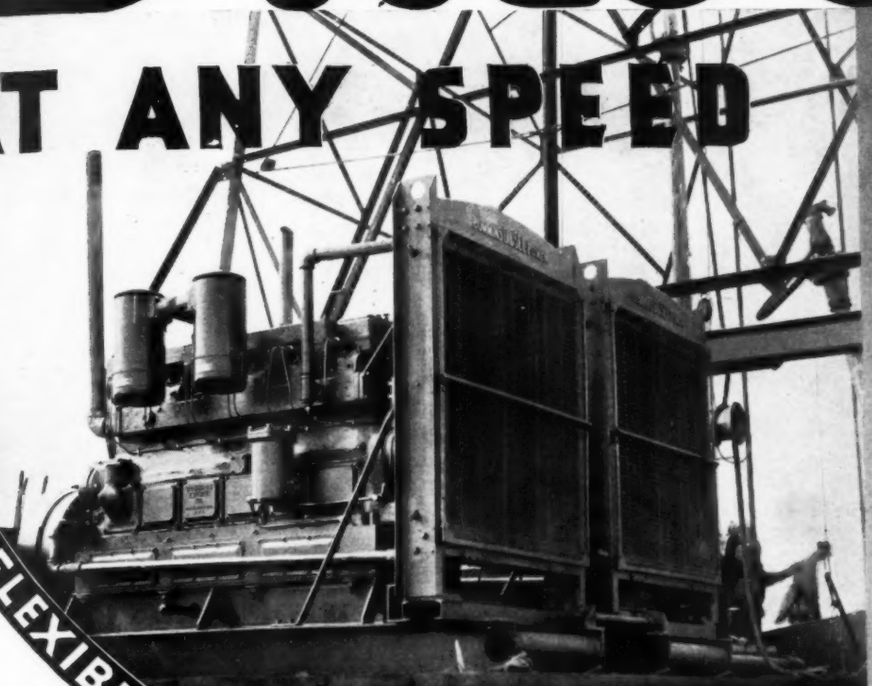

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Intermittent Gas-Lift Flow

Intermittent gas-lift operations are rather widely scattered but do not appear at this time to exist in large numbers in any single field.

The Hughes plunger-lift type of intermittent flow is operating in various fields in California, Louisiana, Oklahoma, and Texas. One of the areas in which the plunger-lift has operated quite successfully is the Keokuk field, Oklahoma, where 4-in. tubing has usually been employed with this method.

The Nixon surface-controlled gas-lift method is being employed as an intermitting device, and is in use in the Lopez, North Sweden, Saxet, and various other fields in South Texas. In this method there is a set of valves in tubing collars at intervals of a few hundred feet apart, which are operated by means of a rod lowered or raised inside the tubing. This rod is suspended on a wire line from the top of the well where it is attached to a piston that moves inside a cylinder suspended from a small derrick above the casinghead. Periodically, gas is admitted to the cylinder, lifting the piston and raising the rod to the point where it will open a given valve, thus admitting gas to the tubing from the annular space between the tubing and the casing and lifting the slug of oil that has accumulated above the valve. The input gas required for this operation is reduced to a small quantity per bbl. of oil lifted.

Trends in Gas-Lift Operations

The deeper fields offer considerable inducement for the use of gas-lift. It should be remembered, however, that increased depth of the well requires more energy to lift a bbl. of oil and this increased energy must be supplied through increased quantity of gas. Increased quantities of gas cause higher velocities and greater friction losses. Therefore, it behooves the operator to consider carefully this condition when adopting his casing program. Some of the wells in the deeper fields are being completed with casing that makes for economy in finishing the well, but will prove a very serious obstacle when reservoir pressures have declined considerably.

It would seem quite possible that in the Schuler and other deep fields in Arkansas gas-lift may come in for some consideration during the coming year. In Louisiana, the Rodessa field is already entering the gas-lift period and the number of these operations probably will increase considerably during the coming year.

Conroe, Flour Bluff, Greta, North Sweden, and the Saxet fields will be fertile areas for gas-lift operations during the next year or two. The 5800-ft. sand in the Saxet field is going to water rapidly but it is a thick sand and conditions are such as to lead to the belief that the life of this sand can be extended for a lengthy period if adequate gas-lift facilities are provided.

Another year may see the Wilmington field in California enter the gas-lift ranks, especially in the Long Beach portion of the field.

The following table indicates the quantities of gas required in the Wilmington field to lift a bbl. of oil at maximum capacity under different conditions of flowing pressure:

Quantity of Gas Required to Lift a Barrel of Oil in the Wilmington Field

Lb./Sq. In. Flowing Pressure	*Cu. Ft. Output Gas Required to Lift a Bbl. of Oil*
1500	8
1400	20
1200	45
1000	75
900	100
800	135
700	180
600	240
500	330
400	470
300	675
200	1025
100	3580
50	8200

The gas-oil ratios at the present time in the Wilmington field are about 500 cu. ft. per bbl. in the Long Beach section, and flowing pressures 1200 lb. or more. At a gas-oil ratio of 500 cu. ft. per bbl., the wells could continue to flow naturally until flowing pressures have declined to about 400 pounds. The question may arise concerning why a gas-oil ratio of 500 cu. ft. per bbl. should be permitted when the required quantity of gas necessary to flow the well at 1200-lb. flowing pressure is only 45 cu. ft. per barrel. The answer is that when wells are beaned back to a low allowable the quantity of gas that accompanies the oil to the well is 500 cu. ft. per bbl., and if the oil is to be produced at all, this quantity of gas will accompany the oil to the surface.

Reservoir pressures in the Turner Valley field, Canada, are high, that is, 800 to 2500 lb. per sq. in., and most of the wells are spaced on a basis of 40 acres to the well, consequently gas-lift operations are not being considered as yet, but within another year the conditions may become such that the use of gas-lift may become necessary in some wells, the depths of which range from 6500 to 7500 feet. The degree of restriction of production in this field will largely determine the time when artificial lifting methods will be required.

The quantity of gas required to lift the oil in the Turner Valley field under given flowing pressures and at maximum capacity is about as follows:

Quantity of Gas Required to Lift a Barrel of Oil in the Turner Valley Field

Lb./Sq. In. Flowing Pressure	*Cu. Ft. Output Gas Required to Lift One Bbl. of Oil*
2000	40
1500	145
1200	235
1000	325
900	400
800	485
700	605
600	745
500	1000
400	1300
300	2000
200	3180
100	7900
50	15,300

Gas-lift has generally been regarded as a method applicable to large daily production. With production severely restricted, the operator is learning the advantages of the use of gas-lift both to reduce capital outlay per well, and to hold lifting costs to a minimum.

A well on gas-lift, Corpus Christi area, Texas. Blow-case installed at separator to reduce back-pressure

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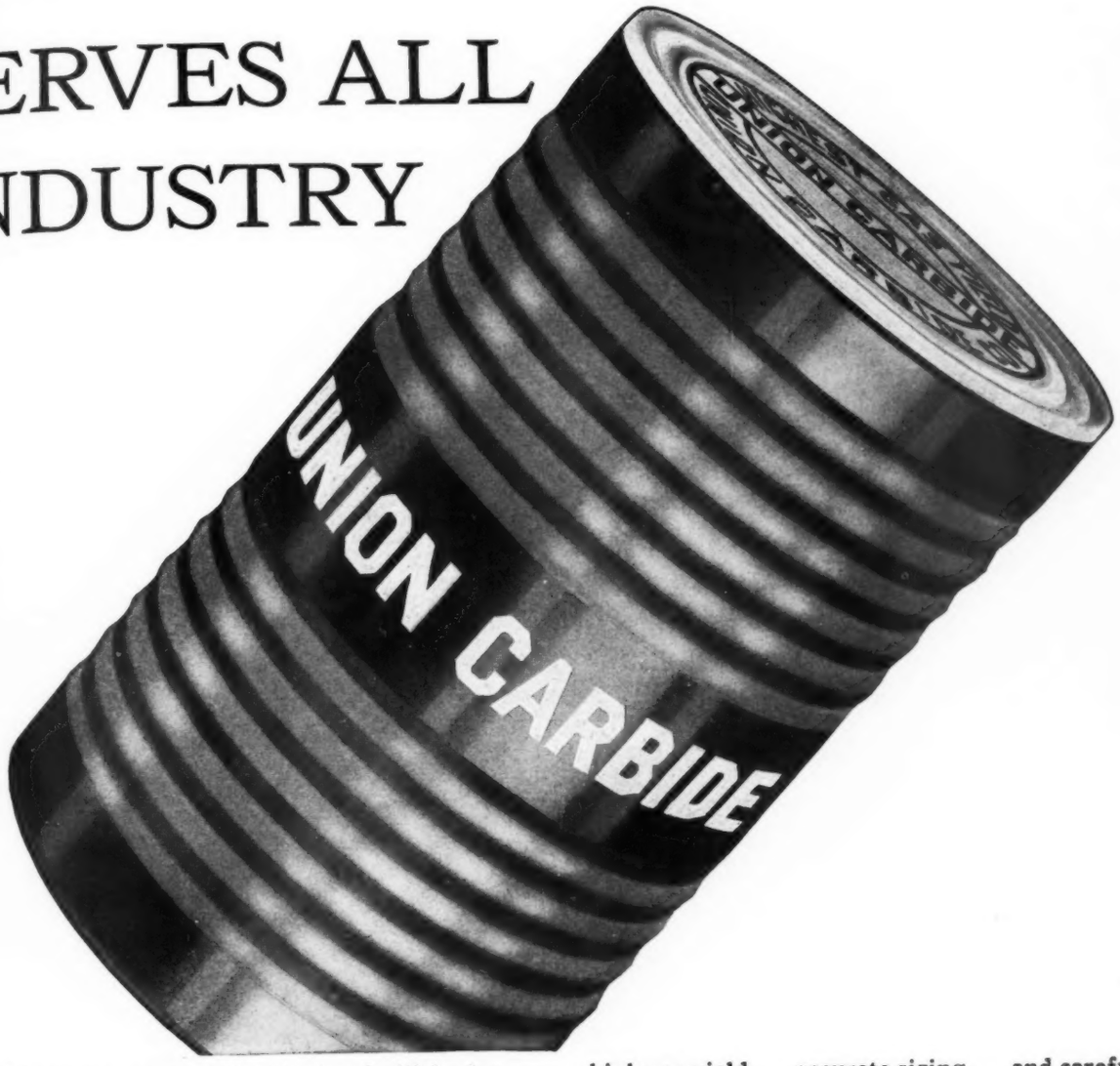

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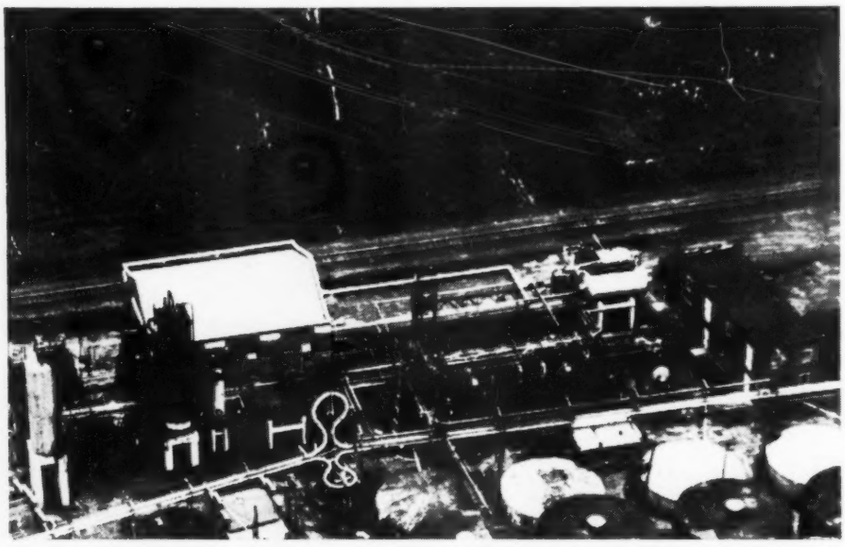
Progress in Lubricating Oil Manufacture

By GEORGE F. FITZGERALD

THE last year has witnessed a continuance of the major trends in lubricating oil manufacture that were apparent a year ago. Solvent refining processes are steadily gaining ground as new installations reach completion. The consumer has accepted the concept of high quality in lubricating oil and demands a high standard of performance in both industrial and automotive uses. Certain lubricating problems, lubrication of hypoid gears, for example, have receded to their proper level and no longer attract an unwarranted amount of attention. The problem of Diesel lubrication seems to be well solved, interest shifting largely to production of satisfactory fuels.



Aerial view of propane dewaxing and deresining plant

Improvements in bearing metals and designs and the use of adequate inhibitors have practically eliminated corrosion, which a short time ago was a very serious problem for automotive and refining engineers alike. Motor fuels and oils will continue to improve gradually without any immediate radical departure from present standards. What changes do occur will be in line with present trends toward moderately higher compression ratios, and faster, hotter engines. These changes will be for the purpose of lowering consumption, improving oxidation stability, and reducing carbon formation in engines.

Forecasts for 1938[1] place lubricating oil production at 20 percent above 1936 figures.

Lubricating quality and stability in use being the important objectives, all refining processes are being studied to determine opportunities for improvement. Research into the actual breakdown effects of distillation confirms[2] the belief that the lack of color stability in commercially distilled lubes from coastal type crudes is due to partial decomposition during distillation. It is interesting to note the regard paid to this relatively slight deterioration as compared with the excessive breakdown associated with the older shell-still operation. Three-stage distillation has been developed to permit removing lube oils as side cuts. Another feature of the method is that harmful high-temperature peaks are prevented by vaporizing the oil within the furnace of the third stage. This operation is said to eliminate most of the serious viscosity losses usually associated with vacuum distillation. Advances in the distillation field are also of great importance because of their effect on subsequent solvent operations that require carefully fractionated cuts in order to be most effective. Concurrent with the study of all processing efficiency is a more general acceptance of the value of the many new processes offered the refiner. Quality must be increased and yet manufacturing costs must not get out of hand. The best answer so far found lies in the extraction of inferior fractions by means of selective solvents. By the use of the proper chemical agent almost any grade of oil can be divided into fractions having a superior and inferior quality. The agent employed depends for its action upon its characteristic power to dissolve one fraction and not the other. Depending on the solvent, either fraction may be dissolved. Both methods of extraction are employed and the results are essentially the same, for the object is to effect a separation of the good and bad oil.

The current success of extraction methods is based upon development of equipment that will intimately mix the oil with the solvent under accurate ratio control without the formation of stubborn emulsions. The contact must be intimate in order that all the oil be treated, and emulsions must be avoided because they hinder or prevent gravity separation. After separation the two solutions must be distilled to recover the solvent. The resultant products of solvent extraction are entirely different in their properties. The extract has increased in viscosity and has a very low Viscosity Index whereas the raffinate has lost some viscosity but has gained 10 to 30 percent in Viscosity Index. The raffinate has also become more suitable for motor lubrication because of increased oxidation resistance.

Solvent dewaxing and refining methods have shown steady improvement. Careful observation of new plants through the construction period and often for months after completion has brought to light many opportunities to simplify design and layout, improve yields and quality, and reduce costs. Control instruments without which continuous processes are impossible have received their share of redesign. The present-day controls make those of five years ago seem crude and cumbersome.

Among the newer manufacturing

(Continued on Page 105)

[1] *Oil and Gas Journal*, March 31, 1938, p. 73.

[2] Brown and Tannich, *Ibid*, p. 80.

(Continued from Page 102)

processes solvent dewaxing has exhibited great activity. Below-zero pour test motor oils are now commonly produced at less cost than were 20-deg. pour test oils a few years ago. A great part of the economy is due to a very high recovery of bright stock from petrolatum. The older centrifuge process was expensive because oil-free petrolatum could not be commercially produced and oils of less than 20-deg. pour test were very expensive to manufacture. Solvent dewaxing has the additional advantage that the same plant will process all kinds of waxy stocks. It is common practice to alternate runs on cylinder stock and wax distillate and even to reprocess old petrolatum stocks to recover the oil not removed by centrifuging. It is a striking fact that the fundamentals of solvent dewaxing were well understood 40 years ago but very little progress could be made with commerical application. The great obstacle was economical and complete separation of the solvents from the oil and wax. It remained for chemical engineering to perfect distillation equipment after which solvent dewaxing was "rediscovered." The stimulus of good business in 1937 accelerated the retirement of old equipment and the adoption of advanced methods for wax removal.

The benzol-ketone process remains in the lead in number of installations. Propane methods are employed where their application to both dewaxing and deresining are most advantageous. In this field much is being done to simplify equipment and to reduce operating difficulties. One of the more recent benzol-ketone installations in the East went into immediate production and shipment of correct pour test oil on the day after starting-up. This contrasts markedly with the delays of one to several weeks encountered two or three years ago. The value of close engineering control is thus demonstrated. The newer plants feature[3] the use of stack gases for the inert blanket and dispense with a special CO_2 generator. Chillers are set at a slight angle to provide better venting of ammonia gas and filters are fed by gravity from overhead tanks. More work needs to be done to provide better washing so as to insure minimum oil content of the wax cake and more nearly uniform quality.

[3]O'Donnell, *Oil and Gas Journal*, February 17, 1938, p. 49.

Other ketones than acetone and methyl-ethyl ketone are being investigated as possible wax precipitants. Chemical structure affects wax solubility and miscibility temperatures, hence the value of any chemical for dewaxing purposes is related to its molecular arrangement. Methyl n-butyl ketone[4] exhibits low wax solubility and a low miscibility temperature for oil. Its dewaxing differential is small and being nontoxic it is safe to use. Should its use become general it will provide an excellent example of the value of modern synthetic methods. Methyl n-butyl ketone is manufactured from secondary hexyl alcohol, which is synthesized from cracked gases by polymerization.

The propane process for dewaxing and deresining may employ either batch or continuous type chillers. In the batch method refrigeration is accomplished[5] by evaporation of solvent and the addition of cold make-up propane that has been chilled by exchange with cold filtrate. In the continuous system[6] the propane-oil solution is forced through conventional scraped-surface chillers countercurrent to cold filtrate. The remaining refrigeration required is provided by adding fresh propane that has been self-refrigerated and, lastly, by a continuous final chiller employing self-refrigeration. The chilled solutions are then fed by gravity to the pressure filters. It is important to note that propane dewaxing is distinguished from the benzol-ketone method not only by the use of a single solvent but by the method of filtering. Although the filters are essentially the same, propane dewaxing requires filtering under pressure because of the volatility of the solvent. The filters are totally enclosed and no provision for an inert gas blanket is needed as there is no chance for infiltration of air. The vapor system is operated as a single closed system and all evaporated propane is recovered and used again. In benzol-ketone dewaxing commercial practice favors vacuum filtration, an inert gas filling the vapor spaces.

After dewaxing, the cold propane solution is warmed by exchange and steam to the proper deresining temperature, which depends upon the type of oil treated and the results desired. The heavier oils lose viscosity rapidly with increasing deresining. For example, 180-viscosity charging stock may lose 20 to 30 seconds for approximately five percent of resins removed. Dewaxing by this process readily produces below-zero pour test oils and the deresining operation so greatly improves filter yields as to make the resin loss unimportant. The resins that are removed do not represent an actual volumetric loss as they have value in the production of very high viscosity gear lubricants.

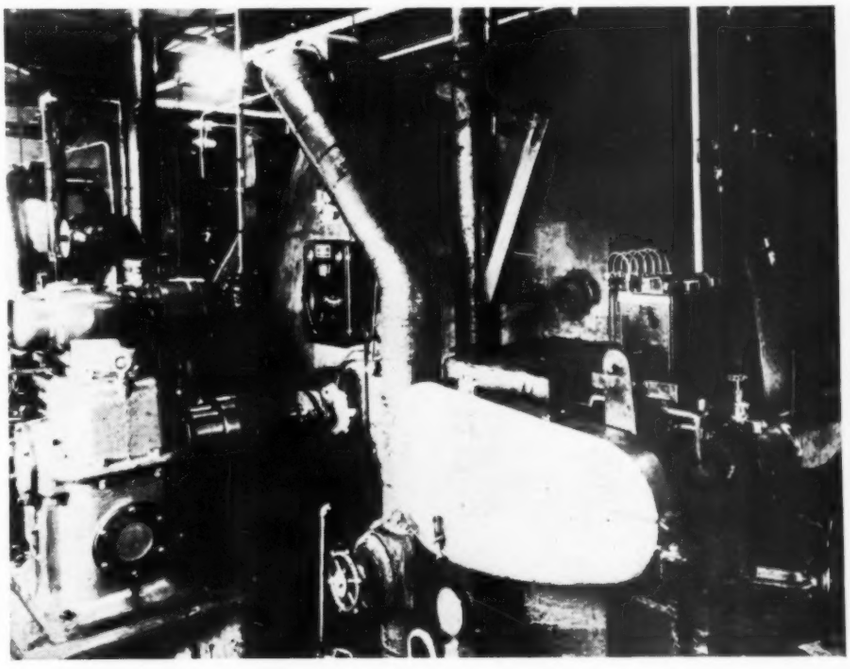
In the Mid-Continent area deresining by propane is displacing vacuum distillation for the removal of asphalt, and acid-treating is giving way to solvent-treating.

New construction of solvent extraction units has been seriously retarded but a large construction program is almost mandatory in the near future.

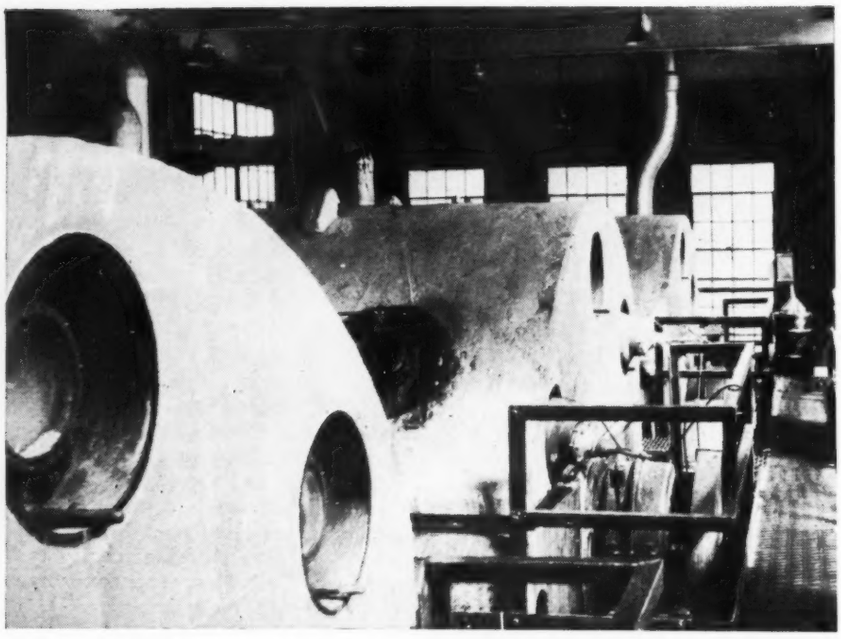
[4]Pokorny & Stratford, *Oil and Gas Journal*, March 31, 1938, p. 96.

[5]McCluer et al, *Ibid*, p. 113.

[6]Cooke et al, *Refiner*, May, 1938, p. 178.



Drive end of pressure filter used in propane dewaxing. Second filter is seen in the background



Rotary vacuum filters used in benzol-ketone dewaxing

The demand for all types of lubricants is increasing and any resumption of industrial activity will build up further demand. The present capacity of modern refining units will not be sufficient if the well-defined trend toward solvent-treated oils continues. Even the aviation trade, which long refused to use anything but the natural, non-solvent-treated, non-inhibited lubes, is learning the value of oils processed by modern methods under rigid control. Even a slight increase in lubricating oil consumption will initiate renewed activity in solvent-treating plant construction. In the meantime existing plants are being remodeled and overhauled. Research laboratories are continuing actively to seek new refining methods and ways to improve present ones.

Among the extracting solvents that are being used more extensively is furfural. The total capacity of plants employing this chemical exceeds 10,000 bbl. per day. Furfural is highly selective and, by reason of its high specific gravity, settling rates are high. The countercurrent packed tower, which has been under development for several years, functions very well when furfural is used. The advantages of the tower are fewer transfer pumps required, less solvent in process, and a saving in ground space and maintenance cost.

In line with the trend toward critical analysis of all refining operations, filtration methods and media are being scrutinized. Solvent extraction and deresining have improved filter rates and have vastly increased the yields from the conventional earths. The proponents of the bauxite type clays have continued their missionary work and have offered material inducement by reducing unit prices. Changing a filter house to the use of bauxite requires much more than a substitution of one medium for another. Operating conditions must first be properly determined.[7] When Fuller's earth is used the usual practice is to burn at one established temperature and to segregate the various burns. When bauxite is used this procedure is unnecessary. The various burns need not be held separate because they all revivify to the same high efficiency. This revivified efficiency is often claimed to be 100 percent of fresh bauxite but plant runs indicate a figure between 80 and 90 percent. The efficiency of used bauxite by volume is, however, about equal to that of fresh Fuller's earth and remains at that level for 100 or more burns. This contrasts very favorably with Fuller's earth, which must be discarded after 6 to 12 revivifications. Bauxite is also of interest to the producer of wax and petrolatum specialties because of its ability to remove odor and taste.

A single burning temperature cannot be used if both neutrals and residual stocks are to be processed. It is a peculiar feature of the bauxite clays that better yields of neutrals are obtained if the clay is burned at the minimum practical temperature and the filter temperature is kept low. On the other hand, bright stock solution filtering results are best when the clay has been burned at a temperature of 1600-deg. fahr. and filter temperatures are maintained at 160 deg. fahr. or higher.

One apparent result of the aroused interest in bauxite is the production of improved grades of Fuller's earth having filter efficiencies 20 to 25 percent greater than the older types. Research and development work in filtering media will continue to the benefit of the refiner and the consumer.

Included in the problems attending filter house operation are the production of such specialties as transformer oils, turbine oils, petrolatums, and waxes. The usual equipment is employed but extra care is required in heating and stripping to obtain good emulsion, odor, and taste. Neutralizing of sour acid-treated oils is also a function of the contact filter department that calls for careful work. Difficulty is frequently encountered because the requisite color and neutrality are not always reached simultaneously. If the charge to the contact plant exceeds two N.N. too much clay will be needed for neutralizing and light colors will result. The recent procedure of higher contacting temperatures[8] and better stripping insures stable color and low N.N. without excess clay.

The refiner who would become a specialist in lubrication must not neglect gear lubricants for a wide range of services including, of course, the automotive. The hypoid rear end that has now become almost universal in new cars introduced a serious problem in lubrication, which was solved by the coöperative work of automotive engineers and grease specialists. This focusing of attention upon gear lubricants has led to a more extensive study of the various types recommended for transmissions and rear axles. The situation was becoming very difficult for jobbers and service men because of the large number of grades they had to stock if complete service for all cars was to be offered. Despite charts and other guides it was often a question which grease or oil was the best for a particular service. In January the Standards Committee of the Society of Automotive Engineers announced an entirely new classification[9] of transmission oils. This classification is intended to facilitate the selection of the most suitable lubricant for a given set of conditions. Obviously all cars of the same make and model do not receive the same usage, hence lubrication must be based upon the type and severity of operation as well as upon seasonal temperature.

[7]Hubbell et al., *Refiner*, March, 1938, p. 104.

[8]Funsten, *Refiner*, June, 1937, p. 241.

[9]National Petroleum Association Report.

(Continued on Page 109)

(Continued from Page 106)

The number of grades for passenger cars has been reduced from five to four and as one of these, SAE 80, is for use at very low temperatures only three will be commonly needed. By establishing viscosity ranges on the lighter lubricants at zero and 100 deg. fahr. and on the heavier ones at 210 deg. fahr. better correlation between test temperatures and service temperatures is expected. Channeling restrictions are continued and are based upon results in actual service inasmuch as no standard test exists.

The oil industry today is becoming increasingly conscious of synthetic methods. Many products once rare or unknown are now available in large quantities by reason of thermal and catalytic processing of crude fractions. Iso-octane and iso-propyl alcohol are being sold in tank car lots. If, as indicated earlier, methyl n-butyl ketone is adopted as a dewaxing solvent the possibility of the petroleum industry providing most of its own processing chemicals comes closer to reality.

To provide the ground work for the synthesis of lube oils an intensive investigation[10] of the chemical nature of all lubricating oils has been made. Processes for creating similar products from cracked gases high in olefin content are being tried experimentally. The increasing production of gaseous olefins from cracking operations must be economically utilized. As the organic chemical market is not capable of absorbing such large quantities it is evident that "condensation of olefins to light products and lubricating oils, the demand for which is very high, appears to be a very important technological problem, particularly as the preparation of ethyl alcohol from ethylene is too expensive."[11] Lubricants that have been synthesized by polymerizing these gases are heavy cyclic hydrocarbons having relatively high specific gravities and low Viscosity Index, but high stability against oxidation. Successful efforts to produce lubricants from a variety of raw materials have been made in various parts of the world. Little or nothing has been said about manufacturing cost but the Italians[12] "have advanced to the commercial scale the production of synthetic gasoline and lubricants by the hydrogenation of coal" and the Japanese are developing the use of shark oil for airplane lubrication. Processes are being developed for cracking hydrocarbon molecules into smaller ones and then with the aid of aluminum chloride catalyst combining them into larger molecules having lubricating qualities. In addition to aluminum chloride many other metallic chlorides and also activated clay, phosphoric acid, and sulphuric acid may be used.

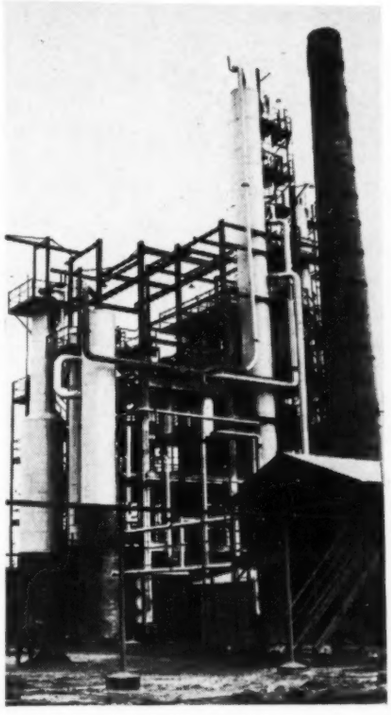
The advances made in synthesis indicate the great value of research and with these accomplishments as a spur more money and more time will be spent to obtain full utilization of crude oil as a raw material. Polymerization and hydrogenation, by converting cracked gases into gasoline and lubes, conserve our diminishing crude supply and their application will extend in a course parallel to the increase in the industry's cracking capacity.

The extensive development of new processes for refining lubricants and their prompt acceptance by the industry have created an almost unlimited market for the equipment manufacturer. Progress in the science of refining is so rapid that even the most modern plant may become obsolete in five years. Under the circumstances a very large part of the refining capacity of the country is due for complete rebuilding. How soon this can be done is a big question but there will certainly be a remarkable refinery construction boom when economic conditions are right. As more plants are erected manufacturing economies will be realized, unit costs will be lowered, and a greater number of refineries will be able to replace outmoded equipment.

The trend toward closer coöperation between oil technologists and the engineering staffs of other industries continues. Automotive design makes every provision for thorough lubrication. In cases of doubt or where radical changes are to be attempted lubricating specialists are called and given every opportunity to state their views and make recommendations. Oil companies devote a great amount of time to determining correct lubricants for every type of service. The manufacturers of heavy machinery of all kinds are following the lead of the automotive industry.

Furfural extraction plant in Germany, 1600 bbl. per day capacity

(Photo courtesy The Lummus Company)



SUMMARY

The acceptance of the chemical engineering point of view by the oil refining industry has led to the adoption of many new processes and now indicates the necessity of carefully evaluating all refinery operations. Each process is considered on its merits and must face the possibility of being replaced. Progress in technology is completely changing the nature of refining and this change will continue rather than diminish. It is reasonable to expect, for example, that the solvents commonly used today for dewaxing and extraction will be superseded by others more effective. Many of them will be synthetics especially designed for the work. New decolorizing media are being sought and definite advances may be expected in the future. No important change in automotive lubrication is expected but the oil industry will continue to keep abreast of any new problems. Synthetic oils are the subject of much discussion as well as important research and development. They will not attain widespread use immediately, as they are intended as a safeguard for the future. Processing equipment continues its admirable march of progress. The fullest advantage is taken of information gained in the field to improve succeeding designs. Observers are agreed that the refining of lubricants will become more and more chemical in its nature and that the findings of science will be carefully applied by the best engineering technique.

[10]Fussteig, *The Petroleum Engineer*, February, 1938, p. 120.
[11]Ibid.
[12]Weidlein, I. & E., *News Edition*, January 10, 1938, p. 11.

Survey of Gasoline Plants in California

By W. L. RIFENBERICK*

IN 1937 few new gasoline plants were constructed. Most of the ideas and trends developed have been improvements in individual pieces of equipment that have been installed to modernize plants, increase capacity, etc., and ideas developed for use in future plants.

Gas Testing

The C. N. G. A. rectified charcoal test method has been more widely accepted. Many companies have changed to the new test. It gives better results in that the rectified G/M has a definite meaning in relation to commercial gasoline.

Some of the companies that formerly used steam to distill the gasoline from the charcoal have changed to ethylene glycol because the C. N. G. A. has not approved the steam distillation, and the companies do not want to run the risk of any legal action by using any other than the approved test procedure.

A committee is working on a procedure for steam distillation, which, when approved, will probably be adopted by those companies favoring that method. Their present apparatus can be easily converted from ethylene glycol to steam.

*Vice-President, Industrial Engineers, Inc.

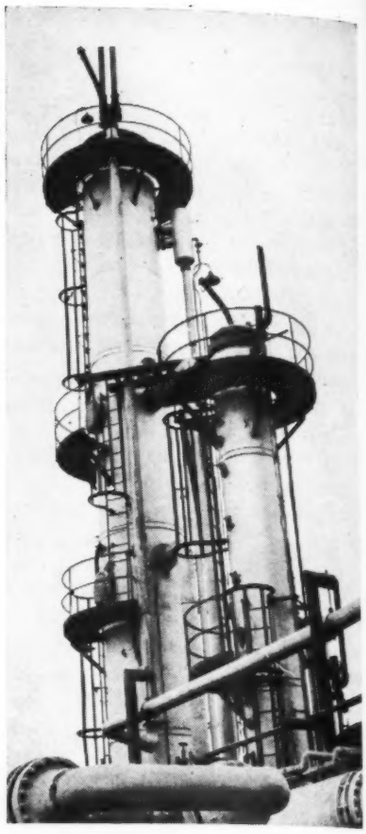
High-Pressure Absorption Plants

The continued production of gas from the San Joaquin Valley fields at high pressure and the necessity of putting the gas into the gas companies' lines at high pressure have resulted in operators giving additional consideration to high-pressure absorption.

Basically all gas should be compressed by the absorption plants to transmission line pressure or the absorption plants should be situated on the discharge of the gas companies' compressor stations to effect a material saving in fuel gas.

High-pressure plants have certain advantages. The cooling load on absorption oil is much less than in a low-pressure plant. The condensing load remains the same. Agitation steam and heating steam requirements are less, so a smaller boiler plant can be used. A reduced cooling load is particularly advantageous if the cooling water is expensive or must be softened to prevent scaling of cooling sections or closed coolers.

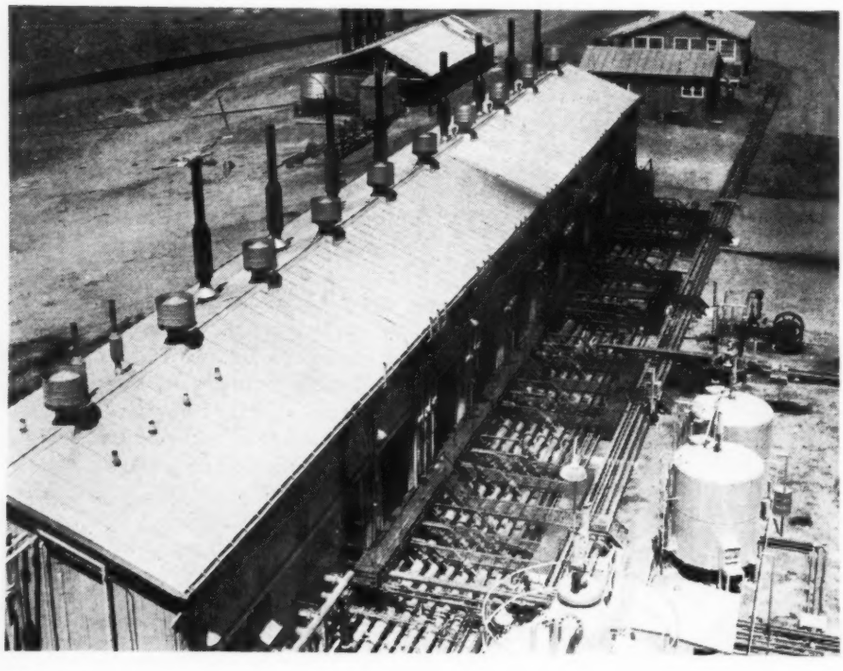
The cost of a high-pressure gasoline plant is much less than that of a low-pressure plant if compressors are not required. If they are, then the cost should be distributed between gas sales and absorption plant. The plant should not bear the cost of compressing the gas sold. The overall cost greatly favors the high-pressure plant in that the fuel required for a 400-lb. plant is only one-half to one-fourth that for 35-lb. operation.



Towers in the Union Oil Company's absorption plant at Dominguez

Increasing Plant Capacity by High-Pressure Absorption

Changing from low-pressure to high-pressure absorption is a good way of changing plant capacity. Last year the Coline Gasoline Company found it necessary to increase the capacity of its Rincon absorption plant. There was the choice of building a new distillation unit and more absorbers or keeping the old distillation unit, which was satisfactory except for the still. Part of the gas was used for gas-lifting at times and a part had to be compressed after absorption for delivery to the gas company's lines. These two facts made it much more economical to keep the investment in the old distillation unit but to add a new still, lean oil pump, and high-pressure absorber. The cost was much less than the cost of building a new low-pressure plant. The distillation unit now has capacity to



Compressor and gasoline rectifier plant at Kettleman Hills. Piping is aboveground to prevent corrosion

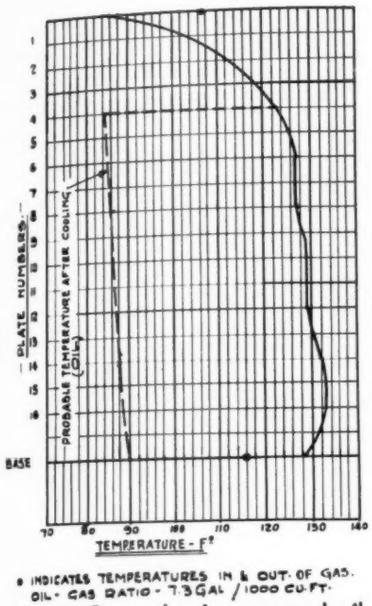


PLATE NUMBERS
PROBABLE TEMPERATURE AFTER COOLING (Calc.)
BASE
70 80 90 100 110 120 130 140
TEMPERATURE - F°
INDICATES TEMPERATURES IN & OUT OF GAS-OIL - GAS RATIO - 7.3 GAL / 1000 CU. FT.

Fig. 1. Curve showing gas and oil temperatures in absorbers

treat about six times as much gas as formerly. The capacity can be further increased by the addition of more high-pressure absorbers.

It may later be desirable to produce butane fuel; this will be very easy to do by high-pressure absorption.

Fat Oil Rectification

Use of the fat oil rectifier in a number of plants to reduce the quantity of recycle gas is also contemplated. Units could be installed in several plants and thus increase the capacity to treat wet field gas. Treatment of recycle gas is like paying for a dead horse. The plant owner cannot afford to install a unit unless it is necessary to increase the capacity of a plant or unless it is desired to reduce the gas consumption in order to have more to sell.

In one plant the installation of a fat oil rectifier would reduce the recirculated gas at 40 lb. by 4,000,000 to 6,000,000 cu. ft. per day. The plant operates at 420 pounds. The net result of eliminating this quantity of 40-lb. recycled gas would be a reduction of one-third in the total plant oil circulation. That is, for the same field gas or the high-pressure gas, capacity could be increased by one-third without the installation of additional equipment. The absorbers have sufficient capacity to treat one-third more high-pressure gas.

The installation of a fat oil rectifier would be an exceedingly cheap method of increasing the capacity of the previously-mentioned plant by a third. A rectifier must be operated at a sufficiently high pressure to produce a reflux from the overhead vapors. If the heating medium available cannot produce a column pressure high enough to condense a reflux if a cooling tower is used, then either mechanical refrigeration or vacuum refrigeration can be used to produce the reflux. If this is undesirable the overhead vapors can be compressed to such a pressure that a satisfactory reflux can be condensed.

Higher Oil Temperatures

Some companies have 125-lb. boilers and want oil temperatures corresponding to 150-lb. steam. It is not necessary to discard the old boilers as long as they are safe and in good condition. Their entire investment can be used by heating the oil as hot as possible with the 125-lb. steam, then putting the oil through the second preheater supplied with 150-lb. steam to act as a final heater. The results of 150-lb. heating can be obtained with a relatively low investment in new boilers.

If it is necessary to use still higher temperatures a small fired heater can be installed in place of the 150-lb. boiler. In either plan the investment is very small in comparison with an entirely new heating system.

Fired Heaters

Fired heaters are being used more extensively in gasoline plants than formerly. This is a return to the original method of heating oil in gasoline plants. The Signal Hill gasoline plant of the Shell Oil Company originally contained 14 fired heaters. In 1926 these were replaced by steam heaters when the plant was modernized. A new distillation unit was built and steam was adopted as a heating medium. At that time the tube stills were heavily loaded and a slight cracking of the oil resulted.

More recently tube still designs in gasoline plants have been modernized. Front wall tubes and roof tubes are used for radiant heat absorption. The conventional convection bank is also used. Cracking no longer takes place, partly because of better designs and partly because of more conservative combustion chamber temperatures. The old trouble from gums in the absorption oil no longer exists, because the fired heaters do not crack the oil.

Absorption Oil Cleaners

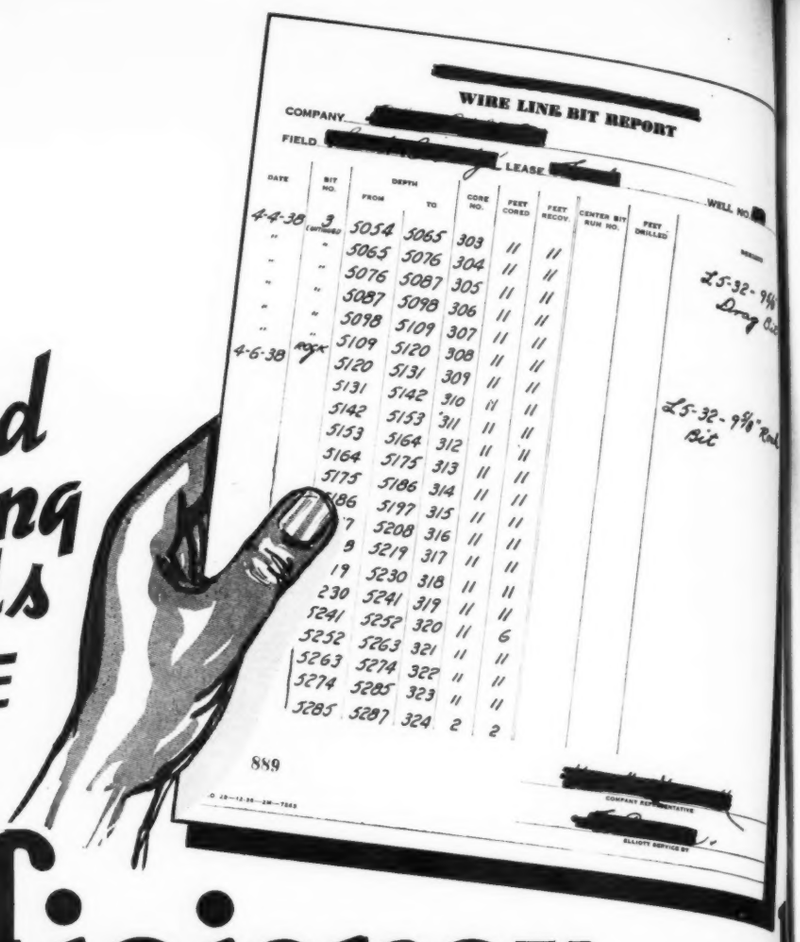
The entrained crude in the wet gas is removed by means of absorption oil cleaners. They are an almost indispensable part of every California gasoline plant today. It is very hard to assign a real worth to oil cleaners because of many factors, but the plants would not be getting the high heat transfer and absorption efficiencies they are today if it were not for the cleaner. Before their use a very liberal dirt factor had to be allowed for fouling of the exchanger and cooler tubes but a heat transfer rate very close to the original can be maintained when a cleaner is used. In addition the absorber trays are clean instead of full of muck. This factor has had a very important bearing on extraction efficiencies.

Steam Rates

One novel use of the fired heater has been made by the General Petroleum Corporation. Exhaust steam is used exclusively in the still. Just enough pumps are operated by steam to supply steam to the still. The others are driven by other means. It would be impossible always to have the correct amount of steam for the oil under this arrange-

Plant No. 4 of Standard Gasoline Company, Ventura Avenue field

Detailed Operating Records PROVE their Efficiency and Dependability



WIRE LINE BIT REPORT

COMPANY [redacted]

FIELD [redacted] LEASE [redacted] WELL NO. [redacted]

DATE	BIT NO.	DEPTH FROM	DEPTH TO	CORE NO.	FEET CORED	FEET RECOV.	CENTER BIT RUN NO.	FEET DRILLED	REMARKS
4-4-38	3 (continued)	5054	5065	303	11	11			
"	"	5065	5076	304	11	11			
"	"	5076	5087	305	11	11			
"	"	5087	5098	306	11	11			
"	"	5098	5109	307	11	11			
"	"	5109	5120	308	11	11			
4-6-38	rock	5120	5131	309	11	11			
		5131	5142	310	11	11			
		5142	5153	311	11	11			
		5153	5164	312	11	11			
		5164	5175	313	11	11			
		5175	5186	314	11	11			
		5186	5197	315	11	11			
		5197	5208	316	11	11			
		5208	5219	317	11	11			
		5219	5230	318	11	11			
		5230	5241	319	11	11			
		5241	5252	320	11	6			
		5252	5263	321	11	11			
		5263	5274	322	11	11			
		5274	5285	323	11	11			
		5285	5287	324	2	2			

889

COMPANY REPRESENTATIVE

ELLIOTT SERVICE BY

*In 1921 Elliott cored the first oil well on a commercial basis, using equipment designed, developed and manufactured exclusively by this company.

The illustration above is a facsimile of one page of a driller's report showing footage cored and core recovery of an Elliott Wire Line Rock Type Cutter Head, from 5,120 feet to 5,287 feet in a wildcat well. Note that this No. 1 Rock Bit cored a total of 167 feet, recovering 162 feet (97%) of core. Detailed figures covering this and other coring jobs are available on request.

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ment were a fixed lean oil temperature maintained from the still.

A constant stripping factor is maintained, however, not by varying the steam rate as is customarily done, but instead by varying the oil temperature to the stripping still. One might suppose there would be too much lag in changing the oil temperature, but there is no more than in changing the steam rate. In either case it is a personal problem of when the operator changes his fires or when the steam rate is changed. This operation is new in California and works very well. It reduces to a minimum the quantity of steam to be condensed.

Corrosion and Piping

More thought is being given to pipe protection. More of the companies are putting all the piping aboveground to eliminate corrosion. The idea is a good one that gasoline plants have used very little. Corrosion on the outside of the pipe is eliminated and it is easy to get at the piping to make changes.

Adequate protection is being given to underground piping, also. One of the companies is removing much of its underground piping and putting it overhead to eliminate serious corrosion. Probably plants will eventually have all piping overhead except such lines as pump suction lines, which of necessity must be low. They probably will be aboveground but lower than the pumps.

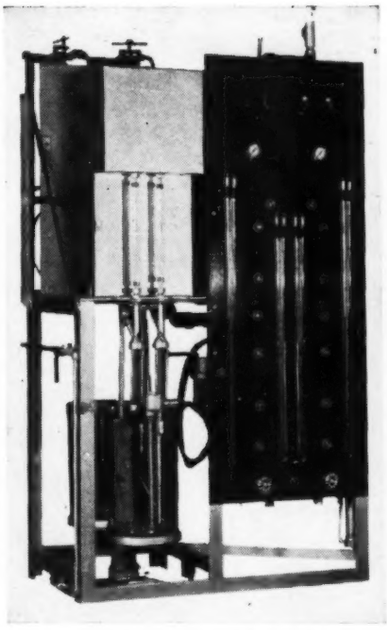
Hydrogen Sulphide Removed

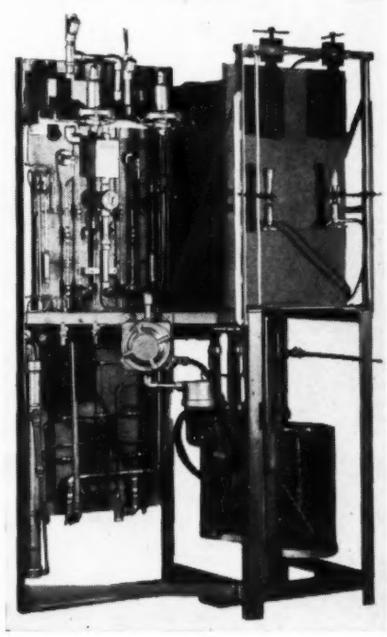
In some of the newer fields such as El Segundo it is necessary to install plants for hydrogen sulphide removal. Usually iron oxide on shavings is used. Some plant managers are also investigating internal corrosion in rectifier equipment, which may be caused by either carbon dioxide or hydrogen sulphide. The problem is serious in a few places.

Absorption

As stated, use of high-pressure absorption is becoming more general; also practically all high-pressure absorbers are being built so that the oil can be removed from the absorber near the top, cooled, then returned. One thing that is retarding the general use of this principle is the uncertainty regarding the validity of the Rogatz patent.

Fig. 1 shows the normal temperature change of the oil in a high-pressure absorber for an oil-to-gas ratio of 7.4. Let it be assumed that the upper four trays are used as heat exchangers while the oil is absorbing large quantities of lighter fractions. At high pressures the absorption of these fractions is extremely rapid as shown by the temperature rise. From this point downward it is largely a problem of absorption of the heavier hydrocarbons and displacement of the lighter ones. The heat of absorption of the hydrocarbons is inversely proportional to their molecular weight; therefore, after the maximum temperature has been attained, the oil can be withdrawn, cooled, and returned to the absorber. From that point downward the oil temperature can be kept low. It can be maintained at 95 deg. fahr. instead of 126 deg. fahrenheit. This would result in a reduction in oil circulation of 50 percent. Such a saving is very important. It is hoped the patent situation will be clarified soon. Oil cooling will be well worth providing in any high-pressure plant.





Above—Front view C.N.G.A. rectified charcoal test apparatus. Below—Rear view

Cooling in low-pressure absorbers is not so important as in high-pressure absorbers; also, the point at which the oil should be cooled is nearer the bottom than the top because there is where the temperature is highest.

High-Pressure Absorbers

One of the major oil companies is building a high-pressure absorber in which some interesting tests will be made. It is proposed to raise the gas rate high enough at some future time to get misting between trays. At the top a gas oil separator is installed to prevent a mist carry-out. The mist can be determined by a clever device developed several years ago. It can be determined at any point between two trays.

The theory is that an appreciable amount of misting will have no serious results in a high-pressure absorber, and that the overall capacity of the absorber can be raised with a resultant lower plant cost. The results of this work will be very much welcomed by the industry when the tests have been made and the results analyzed. It is believed that the results will be made public at such time as the company is satisfied with the tests.

Salt Water Cooling

The use of salt water for cooling is not new in gasoline plants but it is being used more extensively. The General Petroleum Corporation is using it in the Wilmington plant. It gives much lower oil, gas, and gasoline temperatures and can be used without serious corrosion.

Chemical Cleaning of Equipment

Some of the companies are purchasing chemicals to control algae in their cooling towers; also, they are treating the cooling tower water with various acids to dissolve the heavy scale deposits on the wooden structures.

Inhibited acids are also being used more extensively to clean the water scale from engine jackets, condensers, coolers, etc. In general the cost is very close to that of cleaning the tubes mechanically, but the tubes can be made absolutely free of scale without damaging the tubes by boring them.

Soft water in closed jacket-water systems is being chemically inhibited to avoid the detrimental effect of pure distilled water.

Compressors

Nearly all the new compressor units installed in California have been the angle type. This type has the advantage that the downward impulse of the engine cylinder is much easier to absorb on a large flat pad when on poor soil than that of a horizontal machine.

Oil Well Pumping Reduced to the Ultimate in Simplicity and High Efficiency

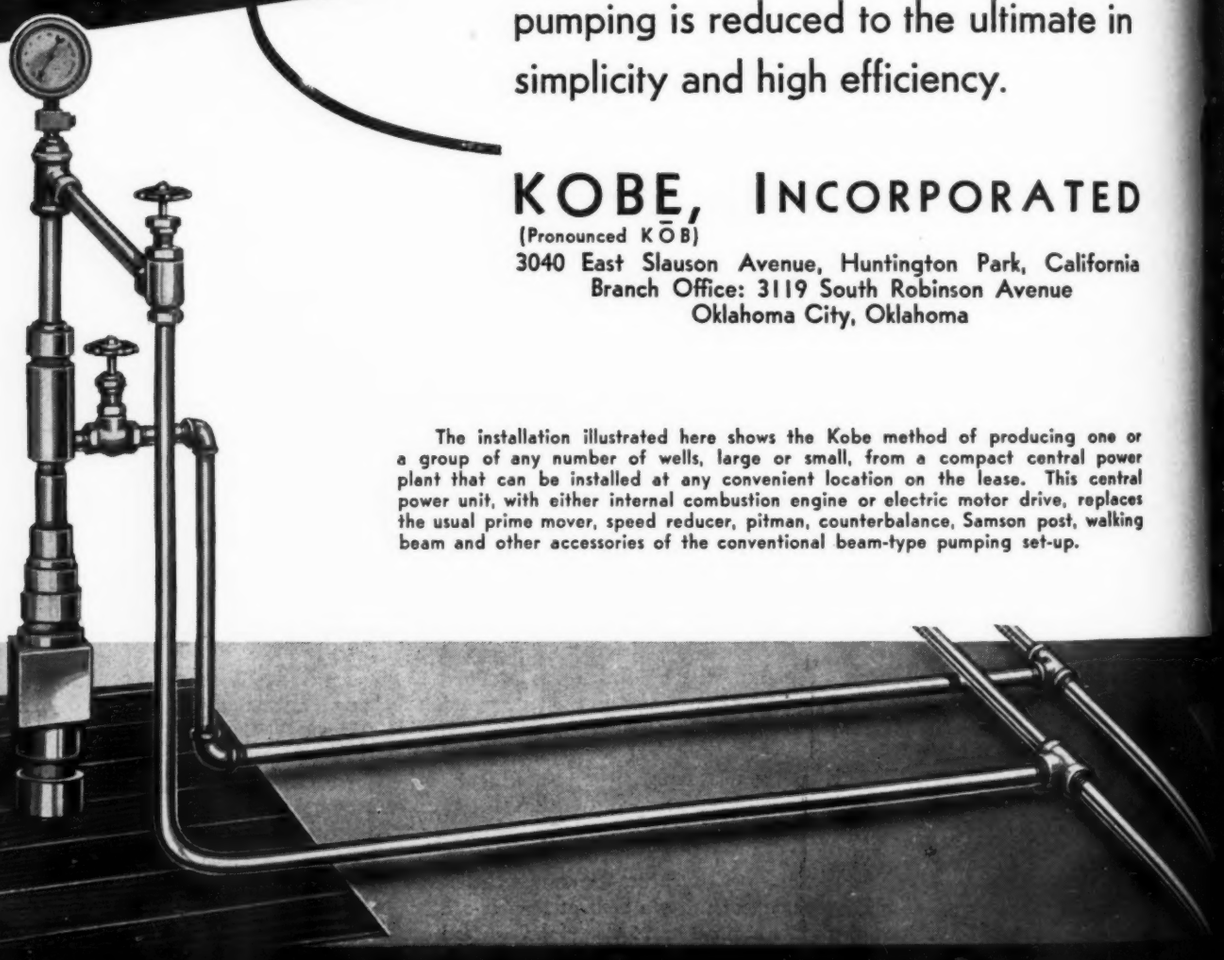
The Kobe All-Purpose Pump is a complete fluid operated oil well pumping unit, comprising all the necessary equipment required to produce oil efficiently under all field, well and operating conditions.

All the mechanical links of the conventional beam-type pumping set-up are replaced by a single stationary pipe to carry the hydraulic fluid. There are no moving parts on the derrick floor or in the well tubing, and oil well pumping is reduced to the ultimate in simplicity and high efficiency.

KOBE, INCORPORATED

(Pronounced K Ō B)

3040 East Slauson Avenue, Huntington Park, California
Branch Office: 3119 South Robinson Avenue
Oklahoma City, Oklahoma



The installation illustrated here shows the Kobe method of producing one or a group of any number of wells, large or small, from a compact central power plant that can be installed at any convenient location on the lease. This central power unit, with either internal combustion engine or electric motor drive, replaces the usual prime mover, speed reducer, pitman, counterbalance, Samson post, walking beam and other accessories of the conventional beam-type pumping set-up.

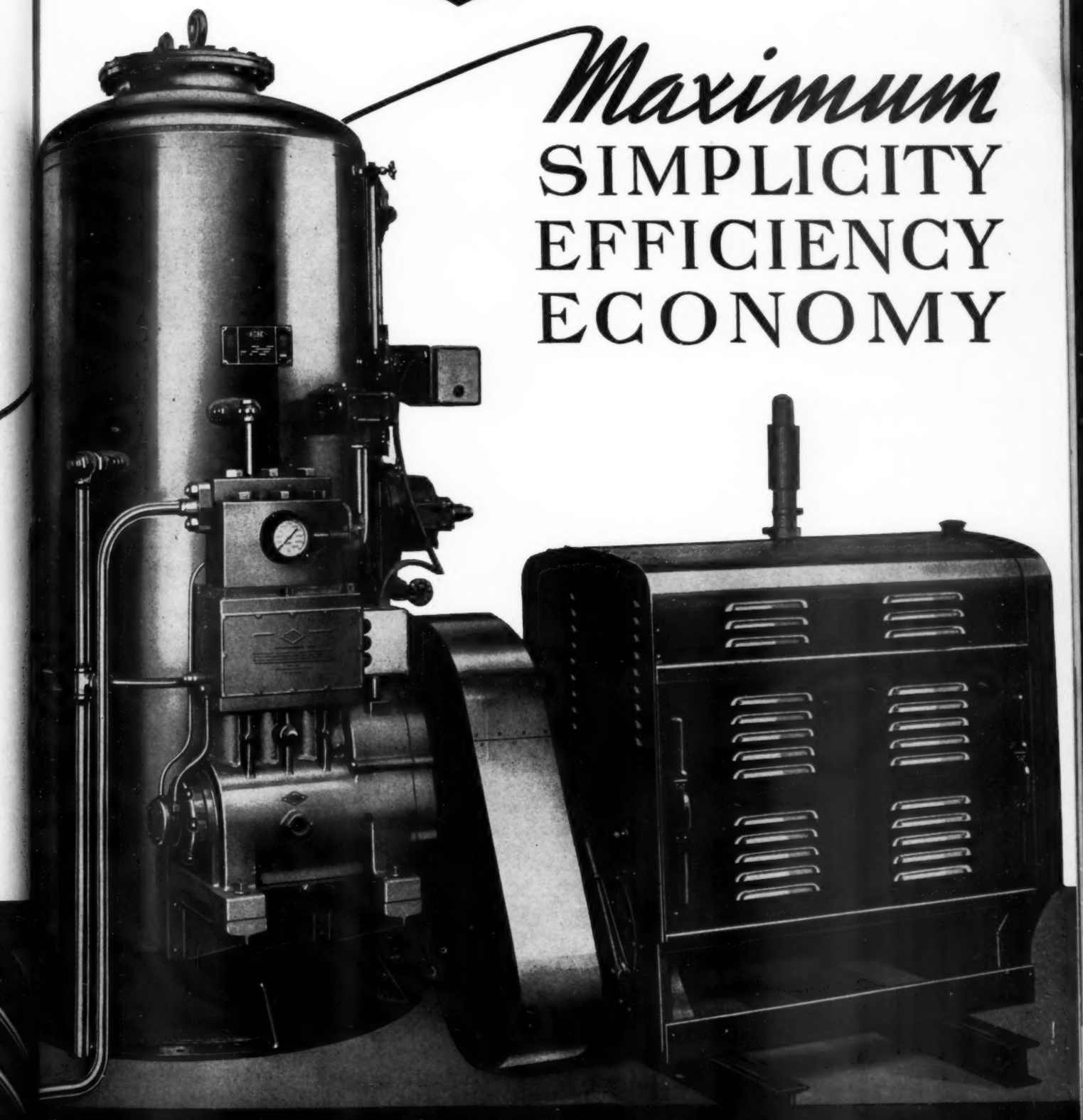
KOBE

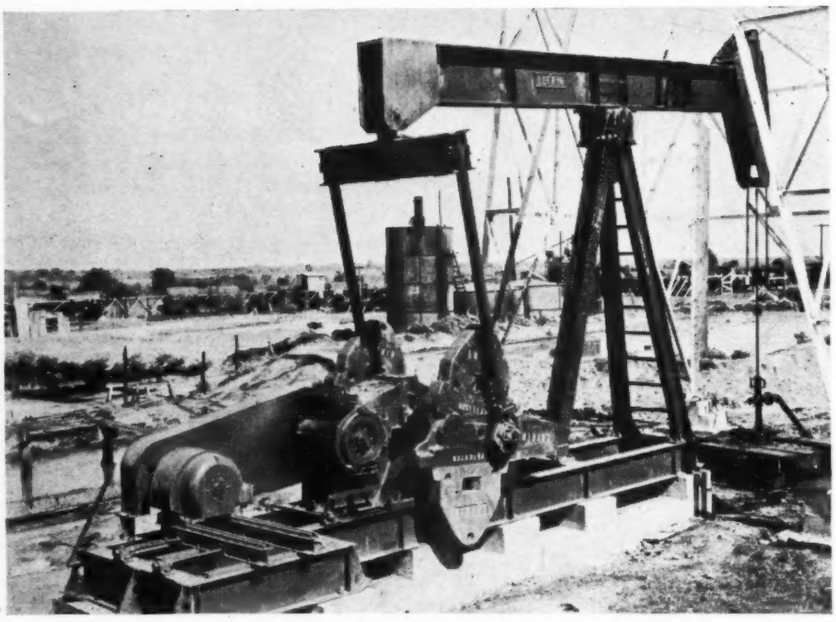
Maximum

SIMPLICITY

EFFICIENCY

ECONOMY





A modern installation of a 25-hp., 1200-r.p.m., splash-proof motor on a reduction gear pumping unit, Talco field, Texas.

By

G. R. PROUT

General Electric Company

Progress in the Application of Electric Motors for Oil-Well Pumping

IN the days when electric motors were first being considered for use in oil-well pumping, the motive power was used not only to pump the well, but to clean it out, drill it deeper, pull rods and tubing, or perform any other service required. The oil-well motor, which was a double-hp.-rated, 2-speed, adjustable varying speed, wound rotor induction motor, was developed for this application. This motor had large overload capacity and very high maximum torque on the high-hp. side to provide fast action on a rod and tubing job, or for running a bailer. This motor was very sturdily built to endure the service required of all oil-country machinery.

Naturally a motor having the variety of characteristics necessary to permit such operation must be a compromise. Some characteristics were modified to obtain other desirable features. The efficiencies and power factors were reduced somewhat in order to obtain high overload capacity and other necessary performance features.

It is also quite natural to expect that the price of the oil-well motor and its control would be high compared with the price of an ordinary induction motor. Thousands of these motors were put into service and performed well, however. Many of them are still in service.

As the petroleum industry progressed, it was quite natural that more efficient methods of production would be found, more efficient equipment used, and more economical operation put into effect.

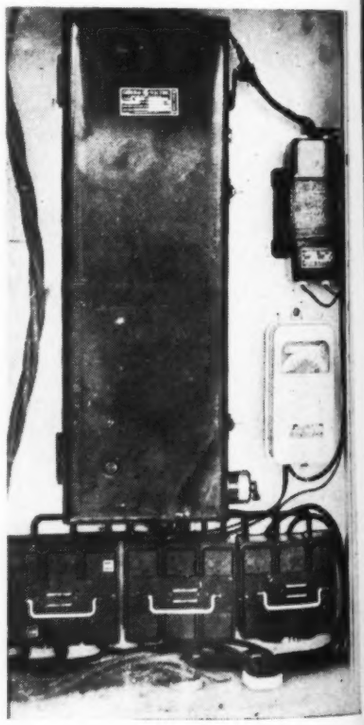
The reduction-gear pumping unit equipped with counter-balanced crank appeared and has almost entirely replaced the old standard rig for well pumping.

Portable servicing rigs were developed and improved, so that now it is the exception rather than the rule to find the motive power on the well doing all the work that might be required at the surface.

More efficient pumping equipment and portable servicing equipment being available, it was obvious that appreciable savings in first cost as well as in operating cost could be realized by the substitution of a motor suitable for pumping only, in place of the versatile but expensive oil-well motor.

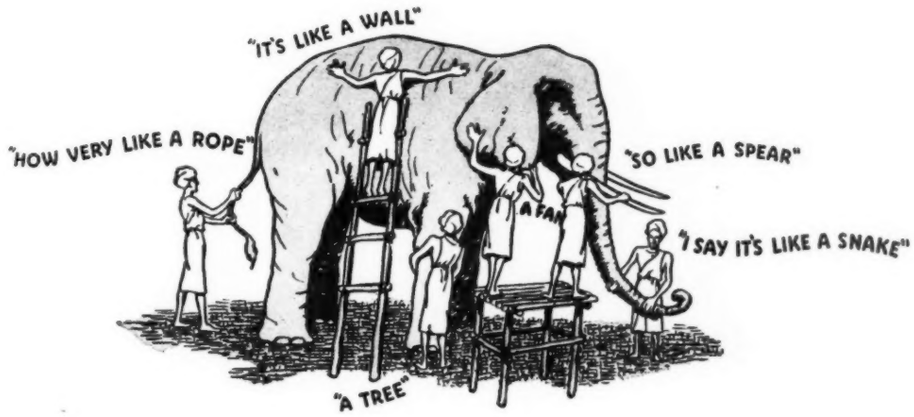
The first step in the transition was from the oil-well motor to the open, squirrel-cage motor. This motor is simple mechanically, requires simple control equipment, and is relatively inexpensive. It has high efficiency and good power factor from half load to full load. It will operate for long periods of time at low maintenance cost.

The open motor and control, like the oil-well motor, was installed in the engine house. Later, however, mechanical variations in construction of



Weather-proof control with cover open for use with 25/17/10-hp. triple-rated motor

The Blind Men and The Elephant . . .



EVERY JOB OF DRILLING is not like every other. One experience or one set of conditions can not be taken to represent all. Is a cable outfit the proper equipment? Maybe! Would a rotary do better—or perhaps a combination of both methods? The answer, again, is "Maybe." There is no real answer to your problem till the problem itself is known.

What *is* your problem? A half dozen advisers who cannot see your *whole* picture, might argue like the "six men of Indostan" and, though "each were partly in the right, might all be in the wrong." There is no universal best method. There are only best methods for particular cases—full cost and ultimate yield being considered.

In drilling a well, the fundamental problem is one of economy. Whatever method you use, reliable equipment and a capable crew are necessary. An analysis assuming these, with your own requirements definitely in view, will enable you to compare, decide, and then proceed, knowing that the method you adopt is the best for your particular job.

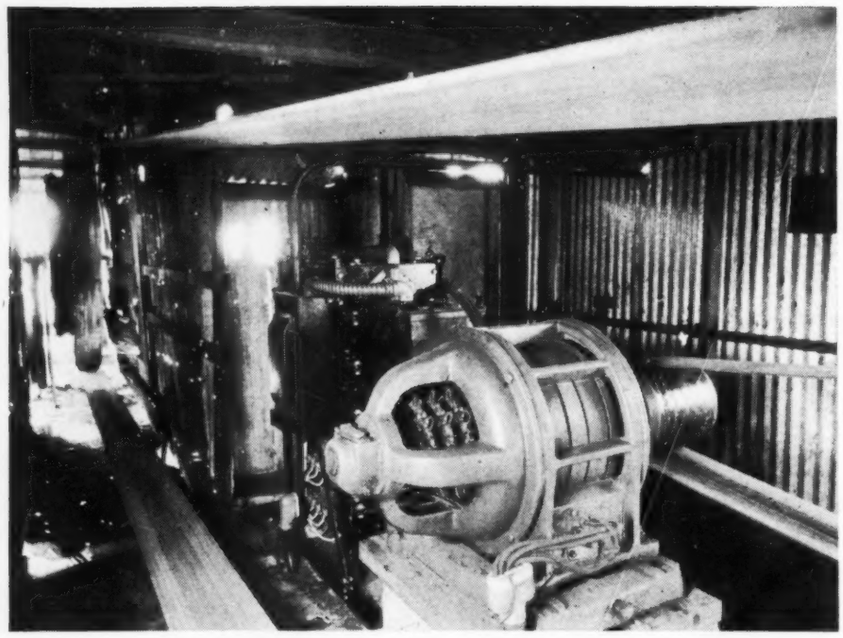
The HIGHER STANDARD

Cable system drilling is economical only with good equipment, properly maintained, and good equipment includes good tools. **Spang Cable Tools** are the standard of comparison for good tools the world over.

SPANG & COMPANY

Butler, Pennsylvania

Manufacturers of **SPANG** *"Higher Standard"* **CABLE TOOLS**



One of several oil-well motors, 35/15 hp., 1200/600 r.p.m., 440 volt, installed prior to 1925 on a standard rig near Oilton, Oklahoma

motors appeared. Among these were the splash-proof features, which permitted motors to be operated in many outdoor locations without shelter. Totally-enclosed, fan-cooled construction for outdoor use in any location and also "explosion-proof" construction became available.

Because of the difficulty of getting portable pulling equipment to the location, it was desirable at some wells to be able to pull rods and tubing with the pumping motor. This service requires appreciably more power than pumping. If a motor large enough to pull rods and tubing were used for pumping, the load while pumping would be so small a percentage of the motor rating that the efficiency and power factor would be low and power cost high. The Star-Delta, double-hp., single-speed squirrel-cage motor was developed to meet this condition. A motor rating that was used widely was the 40/15 hp., 900 revolutions per minute. This motor, when connected on the 40-hp. side, will do a rod and tubing job on wells 3600 ft. deep in acceptable time. This type motor is available in larger sizes for use on deeper wells.

This motor is used on 15-hp. connection for pumping. The efficiencies and power factors of the motor from 7½ hp. to 15 hp., on the 15-hp. connection, are appreciably higher than they would be if the motor were operated on the 40-hp. connections at these light loads. This permits better operation at lower power cost. Furthermore, the well can be started on the high-hp. rating and then after the rig is running, the motor can be switched to the low-hp. side. This is a desirable feature on crooked wells or on any wells that are hard to start.

The same motor is advantageous where potentials must be taken. The motor can be operated on the high-hp. connection, the stroke lengthened, and the pumping speed increased by changing sheaves, for the duration of the test. The motor can then be changed to the low-hp. connection for efficient pumping operation at reduced pumping speed and stroke after the test period is ended.

Because of natural causes for change, in any producing area, it is always a problem to decide the size of equipment to use on account of the difficulty of estimating what production conditions will be during the life of the field. The problem is only complicated by the additional, artificial changes caused by proration.

In order to attempt to alleviate the problem to some extent, the triple-rated squirrel-cage motor was developed. This motor has three hp. ratings, which are obtained at the same speed. Although the early motors were rated 25/15/9 hp. or 40/25/15 hp., later motors were rated in the ratio of 1.0/0.7/0.4 so that the 25/15/9-hp. motor became the 25/17/10-hp. and the 40/25/15-hp. became the 40/28/16-horsepower.

A production man considering the problem of equipping wells for pumping might have definite information that 6 hp. is sufficient to handle the well under existing conditions. He might have additional information indicating that the loads would gradually get heavier and ultimately might require 22 horsepower. If it is his desire to select a motor of suitable capacity for the ultimate need of 22 hp. and yet to obtain efficient operation under present conditions, as well as under any conditions up to the maximum, he can select a 25/17/10-hp. triple-rated motor for the job. The motor can be operated on the 10-hp. connection at high efficiency and power factor until the load reaches 10 horsepower. The connections can then be changed to the 17-hp. terminals and efficient operation obtained up to that load. When the load exceeds 17 hp., the connections can be changed to the 25-hp. terminals.

The triple-rated motor can be provided with inexpensive single-rated control, or with the more flexible and more convenient triple-rated control.

The single-rated control requires the connections at the motor terminal board to be changed in order to change from one hp.-rating to another. This is no serious matter if the changes are to be infrequent.

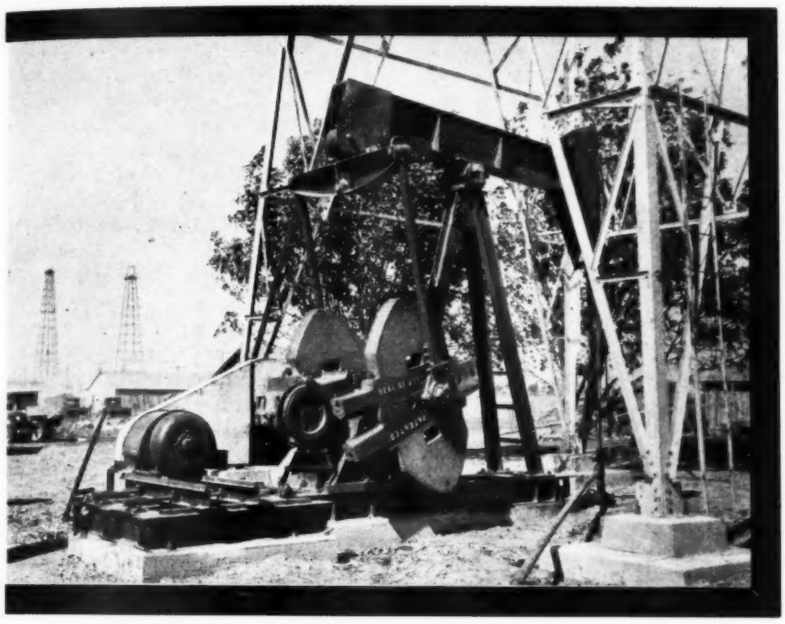
If the motor is to be used in such a way that changing from one hp.-rating to another is required frequently, then the convenience of triple-rated control, which permits easy changing from one rating to another, is desirable.

Four different forms of the squirrel-cage motor are being used to pump oil wells: first, the normal-starting-torque, normal-starting-current motor, which is the least expensive and most widely used motor; second, the high-starting-torque, low-starting-current motor, commonly called the high-torque motor; third, the normal-starting-torque, low-starting-current motor, often called the normal-torque, low-current motor, and fourth, the high-slip motor. All have been used to an appreciable extent.

All the above-mentioned types of motors except the high-slip motor have one characteristic in common—a relatively small change in speed occurs with change in load. The high-slip motor differs in this respect, however; its speed changes with load variations to a much greater extent than that of any of the other forms.

This characteristic makes the high-slip motor particularly applicable for driving such machines as punch presses, shears, and other machines where the work to be done is completed in a very short time. This type of

WHY Producers in Rodessa and East Texas Save Money With Purchased Electric Power



Producers in East Texas and Rodessa oil fields save money with purchased electric power because their experience with various other forms of power has enabled them to place a fair value on the many collateral advantages of purchased electric power. Because of these many advantages, purchased electric power is considered by many successful operators to pay intangible dividends in addition to being a dependable source of energy.

Let us begin now to make a survey to see what electric power can do for you. We have a staff of capable engineers who will gladly make the survey without cost or obligation.

Oil Field Offices: GLADEWATER - LONGVIEW - HENDERSON - KILGORE
General Offices: SHREVEPORT, LOUISIANA

SOUTHWESTERN
GAS & ELECTRIC COMPANY

Here's My Territory.....

Here are My Advantages.....

—says REDDY KILOWATT
your electric servant.

- Low first cost and low maintenance cost.
- Low fixed charges (taxes, interest, insurance, depreciation, etc.)
- Less trouble, fewer repairs, smoother operation, easily moved.
- Longer life — higher salvage value.
- Smaller warehouse stock of repair parts.
- Fewer accidents and less fire hazard.
- Easy to start in any weather.
- Operation can be controlled automatically.
- Counterbalancing easily accomplished.
- Accurate records easily kept.
- Less shut-down time.
- LOWER OVER-ALL COST, PER BARREL, OF FLUID LIFTED.

motor, when driving such a machine, slows down appreciably when loaded. This slowing down permits the flywheel of the machine to release energy to help do the work during the short time of punching or shearing the metal. After the work is done the motor accelerates the flywheel, thus storing energy in the flywheel in preparation for the next punching or shearing operation.

The high-slip motor characteristics provide certain advantages for oil-well pumping under some conditions. The degree to which these advantages may be gained varies with conditions and it can not be said that the high-slip motor is the best motor to use for all conditions of well pumping.

Inherent characteristics of the high-slip motor are high starting torque and low starting current. If low starting current in the larger sizes is a vital factor, however, low-starting-current motors, of either the high-torque or the normal-torque type, should be considered, because both motors have lower starting current than the high-slip motor.

The lower starting current of the high-slip motor is ordinarily unimportant where purchased power is used or where the motors are small. When an operator is generating his own power and the motors are large compared with the generating plant, this is an important advantage. This same advantage to an even greater extent is afforded by the low-starting-current motors of both the high-starting-torque and normal-starting-torque types.

The characteristic of high starting torque of the high-slip motor permits starting a well without rocking. In larger sizes, however, the starting torque of the normal-starting-torque, normal-starting-current motor is frequently sufficient to permit starting the well without rocking. The high-starting-torque, low-starting-current motor of any size usually starts a well without rocking, and smaller sizes of this type motor are frequently used.

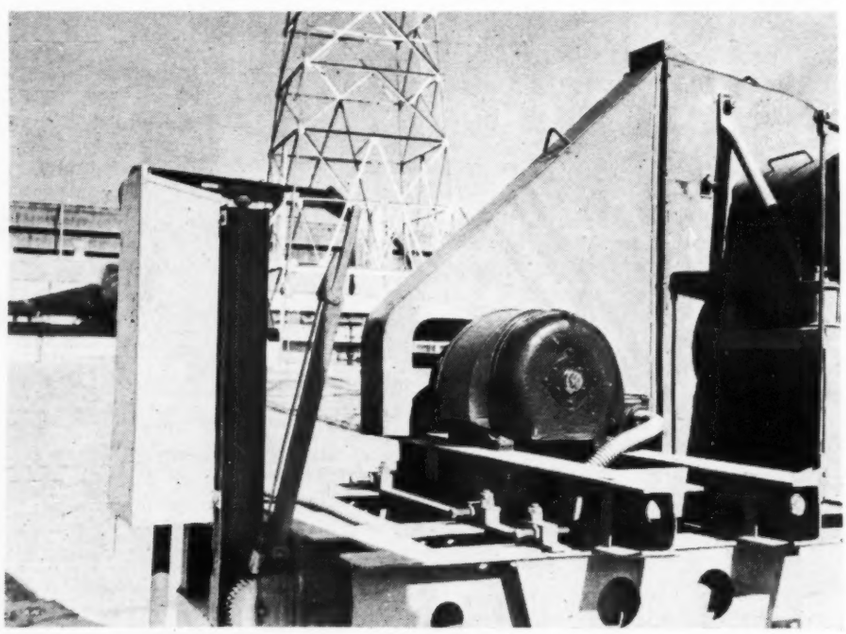
The load-speed characteristic of the high-slip motor may be advantageously used in some cases. The fact that the high-slip motor slows down as the load increases, reduces the power peak input to the motor on a pumping load. The amount of slow-down actually obtained on a pumping well varies with the flywheel effect in the system. If the flywheel effect is high, the slow-down will be less than if it is low. The power-input peaks to the motor will also vary with the amount of flywheel effect in the system. The slowing-down provides a cushioning effect, which may seem desirable, but if a certain number of strokes per minute is required, the average speed of the crank must be the same for the high-slip motor as for the normal-slip motor. If the high-slip motor slows down during a part of the stroke and drives the crank at less than the average speed, it must accelerate the crank and drive it at greater than the average speed during part of the cycle so as to maintain the proper number of strokes per minute. As the speed of the normal-slip motor varies less with load, the crank speed remains more nearly constant. Some experts on oil-well pumping state that the best results are obtained on a pumping well when crank speed is constant, if the length of stroke and number of strokes per minute are properly selected for a well of a certain depth. If this is true then the normal-slip motors should be desirable, because they more closely approximate this condition.

Nevertheless, when an operator is generating his own electric power, the reduction in power peak input to the motor may prove to be a material advantage even though some other disadvantage may be incurred. The reduced power input on the rod and counterbalance peaks will cause less variation in power plant loading and may permit better voltage maintenance at the power plant and better overall operation. This problem varies with motor sizes, generator sizes, and other factors.

The efficiency of the high-slip motor is three to eight points lower than that of the normal-slip motor. At a constant load the normal-slip motor will use less energy than the high-slip motor to do a given amount of work in a definite time. The rate of energy consumption of an oil-well pumping load varies. The rate varies over a wider range when a normal-slip motor is used than when a high-slip motor is used. The current losses in a motor are the principal losses and as these losses vary with the square of the current, the losses at the peak points on a pumping cycle will be materially higher in a normal-slip motor than in a high-slip motor because the current peak is higher in the normal-slip motor. This will tend to reduce the difference in energy consumption of the normal- and high-slip motors, but not in direct proportion, because most of the energy saved at the peaks is added to the valleys. It is possible to conceive a duty cycle that would actually show a saving in total energy in favor of the high-slip motor. It would not be expected, however, on a properly balanced pumping well, although conditions might be such that the difference in energy consumed by the two types of motors might be very small.

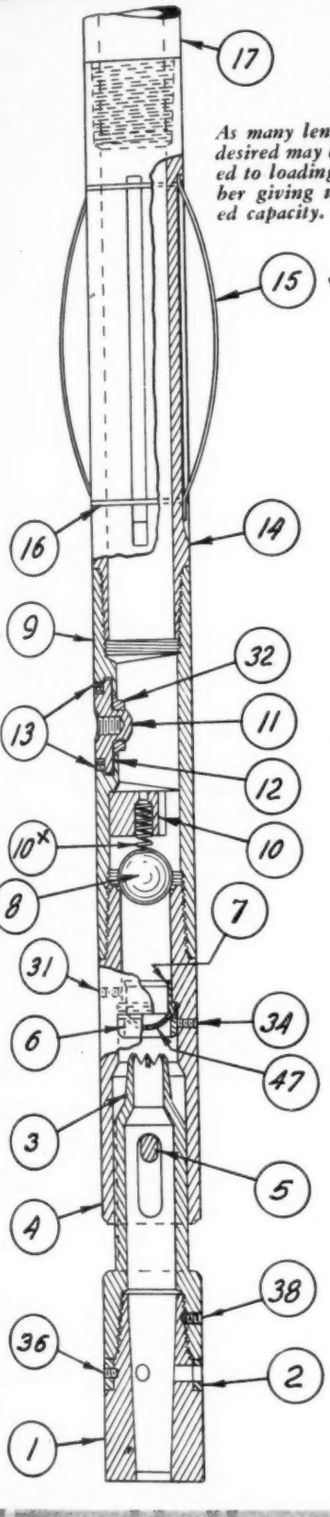
In any case, the saving in total energy would not justify a reduction in motor capacity equivalent to that of substituting an intermittently-rated high-slip motor of the same horsepower as the continuous rating of the proposed normal-slip motor.

The demand charge should not be greater for a normal-slip motor than



A 25-hp., 1200-r.p.m., splash-proof motor with weather-proof control, installed on a pumping unit in Oklahoma

DOWN! DOWN! TO REACH THE RICH TREASURE



As many lengths as desired may be added to loading chamber giving unlimited capacity.

1. Shoe.
2. Adj. Mixer Ring.
3. Disc Breaker.
4. Disc Holder Section.
5. Disc Breaker Stop Pin.
6. Disc Holder.
7. Disc Seat Bushing with Packing Ring.
8. Steel Check Ball.
9. Unloading Chamber.
10. Check Ball Stop.
10X. Check Ball Stop Spring.
11. Unloading Door.
13. Unloading Door Lock Screw.
15. Guide Spring.
16. Guide Spring Lock Ring.
17. Loading Chamber.
31. Disc Seat Bushing Lock Screw.
32. Unloading Door Gasket Nut.
34. Disc Holder Lock Screw.
36. Mixing Ring Set Screw.
38. Disc Breaker Lock Screw.
47. Sealing Disc.

LIGHTNING QUICK IN ACTION

MINIMUM OF PARTS AND REPLACEMENTS

SIMPLE! SURE!

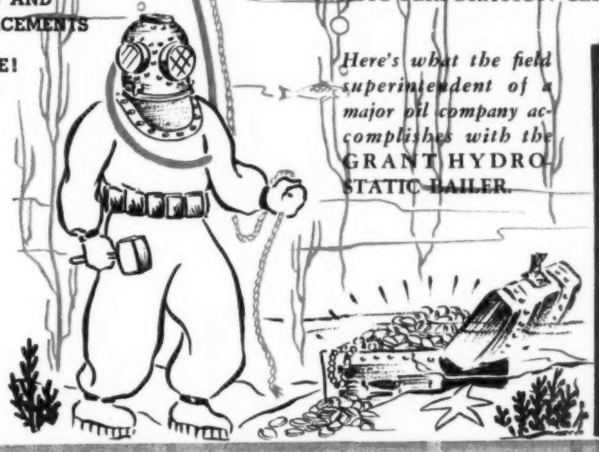
AS THE deep-sea diver removes the sand to uncover *rich treasures*... so does the GRANT HYDROSTATIC BAILER remove the hard, packed sand to reach the BLACK GOLD that is YOUR treasure.

The GRANT HYDROSTATIC BAILER is quick, positive and automatic. Its powerful surging action develops almost unbelievable force. Where other tools have been unable to break down bridges or break up hard-packed sand the GRANT HYDROSTATIC BAILER with its amazing capacity does the job quickly and easily.

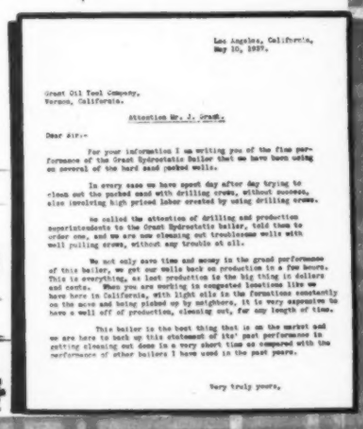
In actual operation the GRANT HYDROSTATIC BAILER utilizes the differential between the normal atmospheric pressure sealed into the loading chamber and the pressure of the standing column of fluid in the well. When the BAILER lands on the bottom of the well, the brittle disc which seals the loading chamber is instantly shattered, and a terrific suction force or vacuum action is set up as the *hydrostatic pressure* forces mud, sand, junk and debris into the capacious loading chamber. Discs are easily and quickly replaced after each run, automatically providing a new valve at a cost that is trifling.

A relief valve near the top of the GRANT HYDROSTATIC BAILER permits the inside pressure to escape gradually as the tool is being raised out of the well, until only sufficient pressure remains to discharge contents of loading chamber without danger to men on the rig.

Send today for your copy of the GRANT catalogue showing this and other famous Grant tools—including the GRANT HYDROSTATIC PERFORATION CLEANER.



Here's what the field superintendent of a major oil company accomplishes with the GRANT HYDROSTATIC BAILER.



Los Angeles, California,
May 10, 1939.

Grant Oil Tool Company,
Vernon, California.

Attention Mr. J. Grant.

Dear Sir:-

For your information I am writing you of the fine performance of the Grant Hydrostatic Bailer that we have been using on several of the hard sand packed wells.

In every case we have spent day after day trying to clean out the packed sand with drilling crews, without success, also involving high priced labor created by using drilling crews.

We called the attention of drilling and production superintendents to the Grant Hydrostatic bailer, told them to order one, and we are now cleaning out troublesome wells with well pulling crews, without any trouble at all.

We not only save time and money in the grand performance of this bailer, we get our wells back on production in a few hours. This is everything, as lost production is the big thing in dollars and cents. When you are working in congested locations like we have here in California, with light oils in the formations constantly on the move and being picked up by neighbors, it is very expensive to have a well off of production, cleaning out, for any length of time.

This bailer is the best thing that is on the market and we are here to back up this statement of its' past performance in getting cleaning out done in a very short time as compared with the performance of other bailers I have used in the past years.

Very truly yours,

GRANT

OIL TOOL CO.

MAIN OFFICE AND PLANT

2042 E. VERNON AVE., LOS ANGELES, CALIF.

Please send me catalogue of Grant Tools.

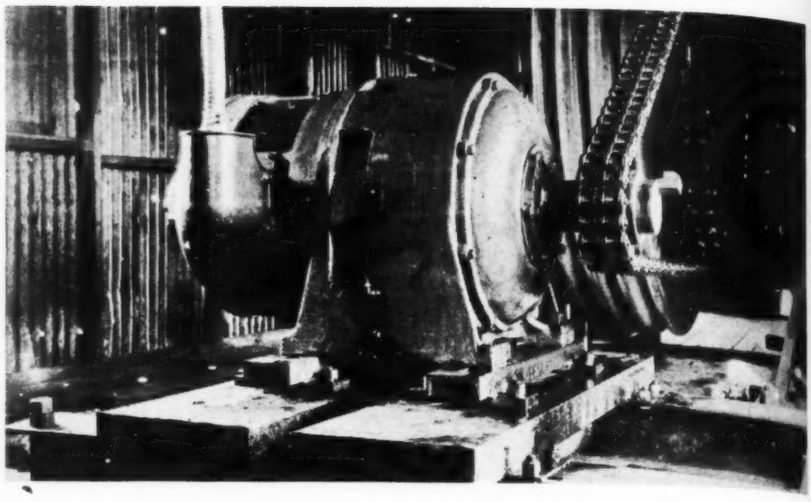
*Name*_____

*Firm Name*_____

*Street and Number*_____

*City and State*_____

*Official Title*_____



A 40/28/16-hp., 90-r.p.m., gear motor with double roller chain driving to a sprocket on the bandwheel of a rig in the Oklahoma City field

for a high-slip motor unless the actual energy consumption during the pumping cycle is greater.

The demand, as used by a power company, is the average rate of energy consumption during a definite period of time, usually 15 minutes. The maximum demand is not an instantaneous demand but rather is the highest average rate of energy consumption during some 15-minute period. Therefore, if one type motor consumes fewer kw-hr. than another motor to produce a certain number of barrels of oil from a well in a day, assuming both motors run 24 hours and the rate of production is constant, the motor taking the greater number of kw-hr. will also have the higher maximum demand. The demand is not established by instantaneous current peaks at starting or during the cycle.

In applying motors to pumping wells, continuous-rated motors should be used if the motor rating is close to the actual horsepower required; that is, if a well is calculated to require 17 hp. and it is decided to use a 20-hp. motor, then a continuous-rated motor of any type should be selected. If a 25-hp. motor is selected to provide a margin of safety, such margin of safety can be obtained only by using a 25-hp. continuous-rated motor, as an intermittent-rated motor of this capacity would not be able to carry more than approximately 20 hp. continuously.

Comparative tests of motors of various types are difficult to interpret because of the fact that in most wells the subsurface conditions are changing from day to day, if not from hour to hour. It is also known that these changes are not always in the same direction insofar as power requirements are concerned.

Tabulated herewith, however, are the results of a test conducted on an installation where four consecutive 24-hour tests were conducted. The high-slip motor ran the first 24-hour period; the normal-slip motor replaced the high-slip motor and ran the second 24-hour period; the high-slip motor then replaced the normal-slip motor and ran the third 24-hour period; the normal-slip motor again replaced the high-slip motor and ran the fourth 24-hour period. The strokes per minute were the same for each type of motor. Sub-surface conditions were evidently changing slightly during the tests, but the results are consistent and hourly readings were taken. (See table at bottom of page.)

These tests indicate that sub-surface conditions were changing in such a way that the load was decreasing somewhat. Nevertheless, the normal-slip motor raised more oil in each 24-hour period than did the high-slip motor and consumed fewer kw-hr., and consequently operated at lower power cost. The kw-hr. per bbl. pumped was less for the normal-slip motor and the demand was less for the normal-slip motor.

One definite disadvantage of the high-slip motor is its higher first cost. In continuous ratings, the cost of the high-slip motor is approximately 25 percent greater than that of the normal-starting-torque, normal-starting-current motor. Naturally, the intermittent-rated high-slip motor is less expensive than the continuous-rated high-slip motor but even the intermittent-rated high-slip motor costs appreciably more than the normal-starting-torque, normal-starting-current motor; however, no intermittent-rated motor is comparable with a continuous-rated motor in continuous carrying capacity.

The same type of control may be used on any of the various types of squirrel-cage motors for well pumping. All types of squirrel-cage motors are being supplied in splash-proof construction for outdoor use in many locations.

Gear motors have also been applied to well pumping. The general practice, however, is not to recommend the gear motor for well pumping except in special circumstances. If a reduction gear is being considered for well pumping under the ordinary conditions of production, it is better to use a reduction-gear pumping unit having a counter-balanced crank that is designed especially for oil-well pumping and to drive this unit with a suitable motor.

In special circumstances, such as those under which stripper wells operate, or where very slow-speed pumping is required, the gear motor is applicable. There have been other special applications where gear motors have been used successfully. The application of a gear motor to a pumping well should be carefully studied, however, in order to insure successful operation over a period of years.

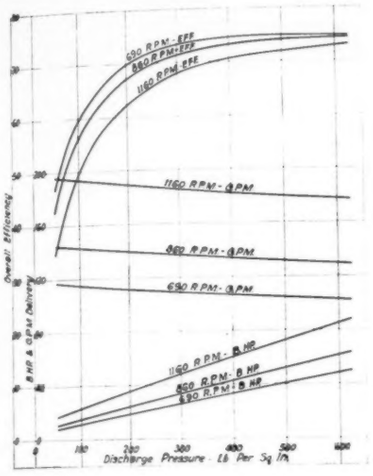
Selection of electric motors for oil-well pumping is not a difficult problem, but all the factors involved in a given problem must be considered in order to apply the type of motor that will meet the requirements to the best advantage.

Test number	*Type of motor*	*Bbl. pumped in 24 hours*	*Kw-hr. consumed in 24 hours*	*Kw-hr. per bbl.*
1	High-slip	242	170	.702
2	Normal-slip	248	160	.645
3	High-slip	242	161	.665
4	Normal-slip	254	148	.572

A New Rotary Pump For Pipe Line and Oilfield Service

By IRVING H. BUCK

MARKING an interesting trend in pumping equipment for handling crude oil is a new rotary pump specially designed for pipe line service and general oilfield use. A rotary pump is commonly regarded as suitable only for handling relatively small volumes of liquid at moderate working pressures; but this type of rotary pump, now in successful use in oil pipe line and gathering line service, has been designed to overcome any such limitations. For example, the four different sizes at present in use range in capacity from 10 bbl. per hr. to 320 bbl. per hr., and in working pressure from 200 to 600 lb. per sq. inch. A still larger pump of this design will soon be available that will have a capacity of 36,000 bbl. per day at a continuous working pressure of 1000 lb. per sq. in., and an overall efficiency between 80 and 90 percent.



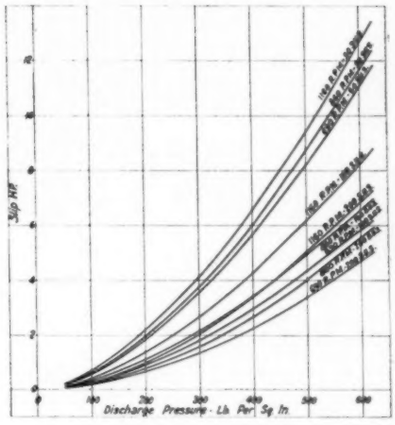
Curves showing characteristics of the 6FB5 rotary pump

Of very compact design, the pump is of the positive displacement type and consists of an 8-tooth pinion mounted on a shaft, which is eccentric to a 9-tooth ring gear and the pump casing. The pinion rotates within the ring gear. Besides having nine teeth the ring gear has also nine lateral openings or ports between the teeth as shown on the accompanying cross-sectional view of the pump. The pinion is revolved by the shaft and the ring gear turns on the pinion as an idler. Suction and discharge of liquid through the pump is provided by abutments or barriers between the suction and discharge ports.

In passing through the pump the liquid is trapped between suction and discharge ports, by the barrier formed: by meshing of the teeth of the pinion and the ring gear at the top or the end of the discharge port and upper abutment of the pump (the teeth of the pinion and the ring gear are shaped so as to make a tight mesh possible); by the close fit of the tips of two pairs of opposing teeth at the lower side of the pinion and the ring gear, and by the close fit of the ring gear and pump casing (the clearances are of the order of 0.001 in. per inch diameter). The space between the teeth increases steadily as the teeth unmesh on the suction side of the lower abutment, and decreases steadily as the teeth mesh on the discharge side of the lower abutment.

The profile of the gear being based on a logarithmic spiral, insures a smooth long-arc contact and thus prevents wear at any one point and so retains a positive tooth seal.

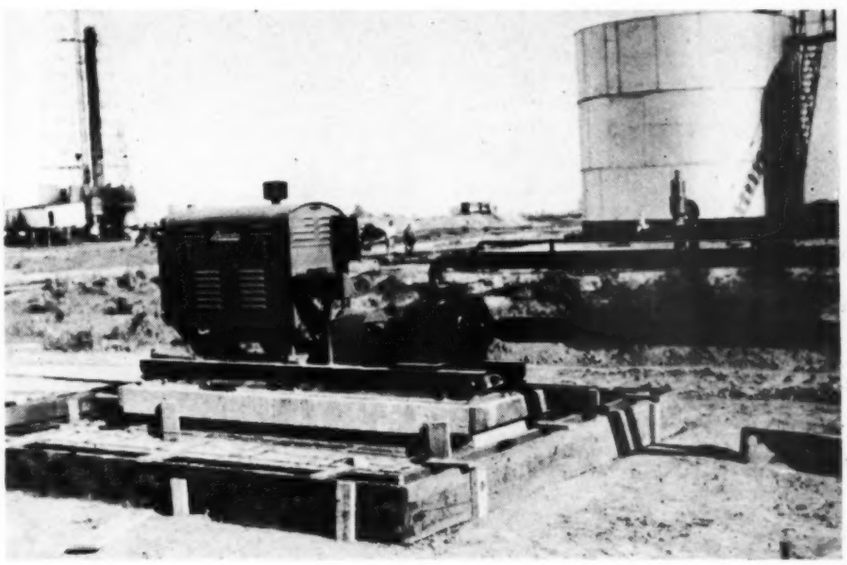
To prevent cavitation when pumping oil containing much gas in solution a centrifugal pump of special design acting as a booster at the suction end has been made an integral part of the pump as constructed for pipe line service.



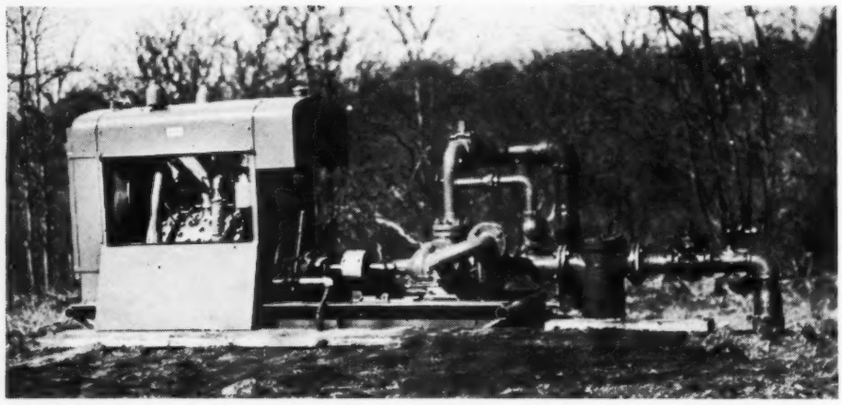
Slip hp. vs. pressure of rotary pump for oils of various viscosity

The design gives the pump many advantages for pipe line and oilfield work. When operating at full speed there is no trapping of the liquid between meshing teeth, because the abutments are correctly placed. This results in smooth delivery, little pulsation, and enables the pump to handle liquids under a vacuum on the suction side.

The two accompanying charts show the typical characteristics of the pump. It will be noted that between 250 and 650 lb. discharge pressures the overall efficiency is uniformly high. Even at engine speeds between 690 and 1160



Type 6FB5, Rio Bravo field, California. Capacity, 310 bbl./hr.; maximum pressure, 300 pounds



Type 4FB8, in operation in field near Tulsa, Oklahoma. Capacity, 175-200 bbl./hr.; maximum pressure, 450 pounds

r.p.m. the average overall efficiency for the size of pump shown is between 75 and 80 percent. The operating speed of the pump permits direct connection to almost all types of power units. The pump is capable of continuous operation at pressures to 600 lb., but it can also operate at intermittent pressures to 800 pounds.

Type	Pump capacities and r.p.m.	Suction and discharge	Weight of pump	Approximate overall dimensions of pump		
				Length	Width	Height
2FB8	19 to 45 bbl./hr. 1750 to 3600 r.p.m.	1½″ x 1½″	50 lb.	18″	10″	7″
3FB8	47 to 103 bbl./hr. 1180 to 2400 r.p.m.	2″ x 2″	140 lb.	25″	15″	11″
4FB8	84 to 182 bbl./hr. 860 to 1750 r.p.m.	3″ x 2½″	327 lb.	30″	22″	15″
6FB5	155 to 265 bbl./hr. 690 to 1160 r.p.m.	4″ x 3″	855 lb.	41″	27″	23″

On rigid tests the volumetric efficiencies obtained when pumping an oil of S.U.S. 40-80 viscosity were:

- 95 percent at 150-300 lb. working pressure;
- 90 percent at 300-450 lb. working pressure;
- 85 percent at 450-600 lb. working pressure;
- 75 percent at 600-1000 lb. working pressure.

In pumping an oil of greater viscosity the volumetric efficiency may be still greater.

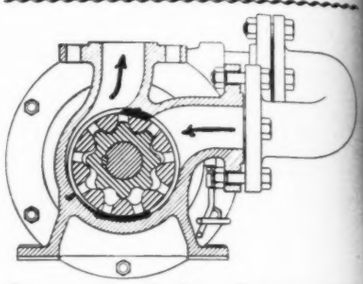
Four sizes of units are available. (See table on this page.)

The compactness and light weight of the pump make it highly portable for oilfield service. Its speeds are such that it can be direct-driven by internal combustion engine or by electric motor.

Tests show that the pump operates without undue wear even when pumping oil containing considerable sand or grit. In the curves showing characteristics it will be noted that this particular design of pump can operate within a wide range of speeds and capacities at a uniformly high efficiency.

Both gears are made of durable steel that can withstand continuous operation with minimum wear and also withstand the effects of corrosive elements found in most crude oils. The fact that wear on the gear teeth is so slight enables the pump to maintain the desirable characteristic of quickly building up high pressure.

This pump, which is being manufactured by the Guiberson Corporation of Dallas, Texas, does not follow the design of orthodox pumping equipment used in the oilfield; its application and performance may therefore be followed with interest.



Cross-sectional view of pump. Upper and lower abutments shown in solid black

Trailer type unit. In use in K.M.A. field and New Mexico. Capacity, 70 bbl./hr.; maximum pressure, 650 pounds

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(Above) The photomicrograph (magnified 100 times) shows the (a) armoring wall of DI-HARD metal perfectly bonded to the (c) parent metal by the (b) fusion zone.

(Right) Molten DI-HARD metal at 2000° F. is centrifugally inlaid at 1500 R. P. M., forming an armored wall having a Brinell hardness of over 600 throughout its entire depth, and after honing, a practically frictionless surface.

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Recent Progress in Pressure Drilling and in the Use of Bottom-Hole Chokes

By H. C. OTIS

NO radically new methods or equipment have been developed in the last year for use in operations at well pressure, but there has been a steadily increasing realization of the possible harmful effects of heavy columns of mud upon the producing zone, and there is a very marked realization of the dangers presented by present high well-head pressures. As a result, more tubing is being handled under pressure than ever before, more companies are drilling-in under pressure, and more interest is being shown in the development and use of equipment that confines high working pressure and even high closed-in pressure to the bottom of the well.

In the latter general class, bottom-hole chokes continue in almost universal use for controlling high working pressures in tubing, particularly where these pressures are so high as to cause freezing when surface chokes are used. In fact, few such wells are operated in any other way.

There has been an interesting development of removable bottom-hole chokes for a somewhat different application. Blank removable bottom-hole chokes have been in use for some time to plug tubing in wells situated in coastal waters when storms, which might cause damage to the surface tubing connections, threaten. On receipt of storm warnings, the operators would run these chokes to a depth of a few hundred feet below the surface, so that should the surface tubing connections suffer damage during the storm, the tubing would still be closed-in. After the storm had subsided, the chokes would be pulled and the wells again put on production.

This operation, although effective, had two objectionable features—one, the amount of labor and equipment necessary to plug and unplug a great many wells, and the other, the fact that the time between the receipt of the storm warning and the arrival of the storm might not be sufficient to permit plugging all the wells. To overcome these two objections, a pressure-operated valve has been substituted for the blank bean formerly used on the bottom of the removable choke. This valve remains open so long as the

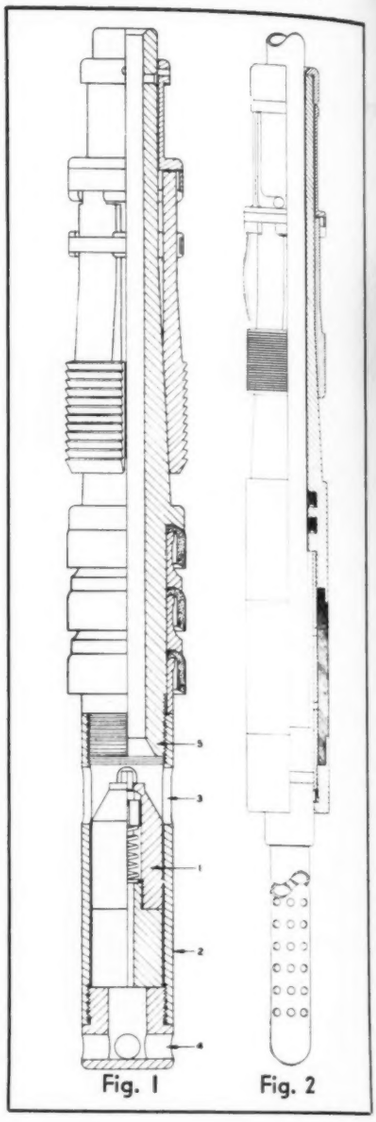
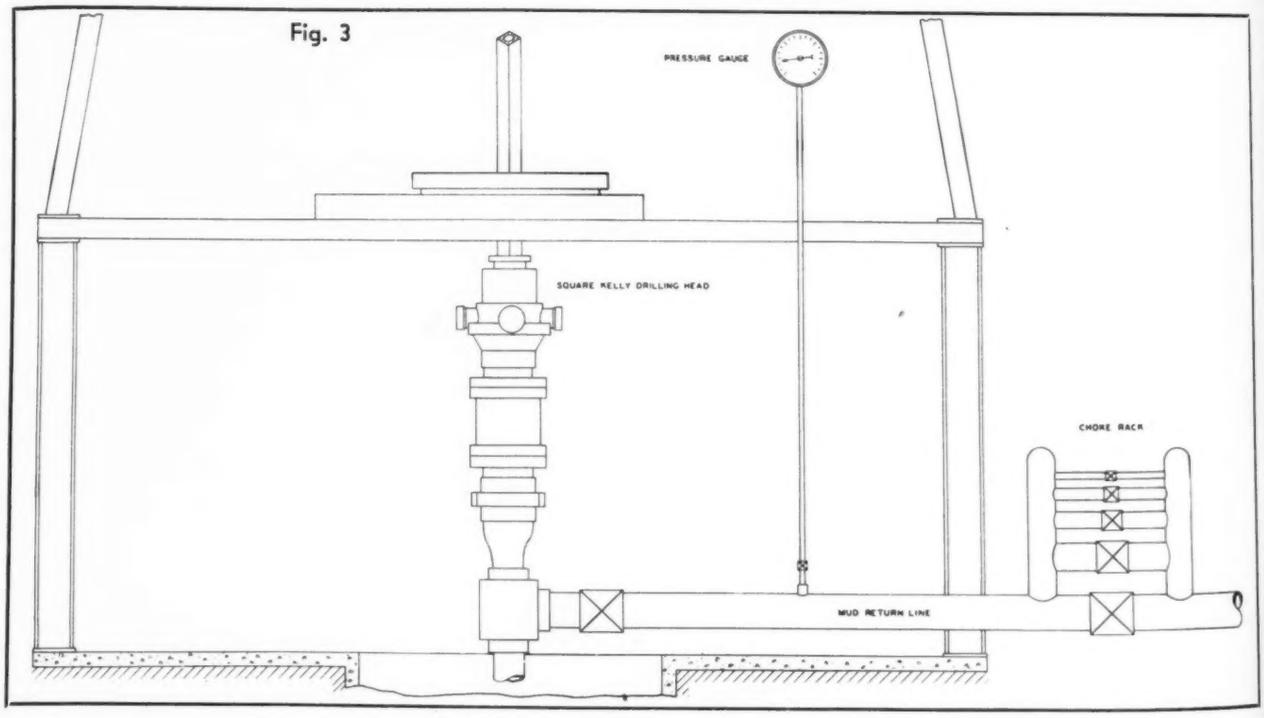


Fig. 1 Fig. 2

Fig. 3



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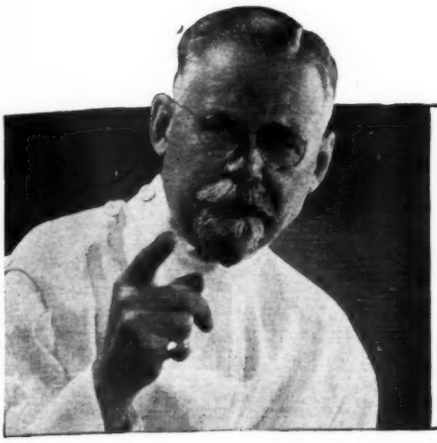

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POLAR CORE ORIENTATION

(U. S. Patents 1,778,981: 1,792,639: 2,089,216: 2,104,752: 2,105,650 and others pending)

The orientation of a core to determine its direction of dip is performed in our Laboratory, to which selected core samples, taken by any type core barrel in the ordinary course of drilling, are shipped from any distance. No special equipment is required at the well, nor is the program of drilling impeded.

The cores received at our Laboratory are first ground into true cylinders and afterwards tested in our automatically operated orientation apparatus, which photographically records the polarity of the core, from which the magnetic North-South axis is located. The results of this method are accurate and reliable. The value of knowing the direction of dip in wildcat wells, or in unexplored deeper zones or defining structures in proven fields is well known.

SELECTION and PREPARATION

1. Type and Size of Samples— Samples with *visible indications of a bedding plane* should be taken from the core barrel by the geologist as soon as the core barrel is returned to the surface and should be marked at that time indicating "Top" and "Bottom".

Core samples of soft formation, or those which easily disintegrate, should be carefully washed of all drilling mud and all other foreign substances. The clean core should then be dipped in Sherwin-Williams clear lacquer of vegetable compound and then wrapped tightly in "Kodapak" with the ends also protected.

Materials which contain heavy mineral grains, distributed throughout, such as sandstones, sandy shales or shales streaked with sand are the most suitable. Pure limestone, dolomite or anhydrite are not workable.

Cores without visible stratification other than breaks along the bedding planes can be used if notation indicating these breaks represent the true bedding is made by the geologist on the envelope containing the core sample.

The samples received should not be less than two (2) inches in diameter and the lengths between perpendicular ends should not be less than three (3) inches. Samples of smaller size, if smooth and unbroken, will be tested at customer's risk.

2. Number and Depth Range— One set of cores or samples shall comprise not less than three (3) and not more than five (5) individual cores or samples taken within a depth range of *not more than one hundred feet (100') in one bore hole.*

3. Precautions in Handling— Cores prepared for orientation should be carefully packed so as to avoid breakage in transit. They should never be left in the vicinity of any direct or alternating current field, or near any magnetic field.

4. Data Required— Samples should be accompanied by a letter giving the following information:

a. Identification of set of samples by well, name, and number and its approximate location by Field, County and State. If desired the well can be identified by a code number.
b. Type of material of samples.
c. Geological horizon of samples.
d. Depth from which each sample was taken.
e. Inclination and direction of the hole at depth at which samples were taken. *This is extremely important* when submitting samples with very low angle bedding planes.
f. Magnetic declination of locality where samples were taken.

METHOD OF SERVICE

Forward samples and information to our Laboratory at 549 East Bixby Road, Long Beach, California, carefully packed to avoid breakage. A comprehensive report on the findings will be dispatched within three days of receipt, or earlier if possible.

The service is strictly confidential.

SERVICE CHARGES

Service charges depend upon the results obtained and are as follows:

a. Determining the orientation from a set of three (3) to five (5) samples $150.00
b. Service charge for running three (3) to five (5) samples through apparatus when samples fail to show polarization $100.00
c. Service charge for three (3) to five (5) samples which after grinding fail to show bedding planes ..... $ 50.00

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flow velocity is less than a predetermined rate, such as that through a 3/8-in. surface choke, but closes instantly whenever flow velocity exceeds this rate. The removable choke is run into the tubing and set at any desired depth. The differential valve remains open and in no way affects production through the tubing so long as the production rate is normal. In event of failure of or damage to the surface tubing connection, the resulting increased flow velocity instantly causes the differential valve to close, thus plugging the tubing. After the damage to the surface connections has been repaired, the differential valve is opened again to permit production at normal rates simply by equalizing the pressures above and beneath the valve.

A removable bottom-hole choke equipped with such a valve is shown in Fig. 1. The valve (1) is shown in its normal open position, at the base of the cage (2). Production is through the slots (3), above the valve (1). Whenever the production rate becomes so great that there is an appreciable pressure drop across these slots, well pressure, acting through the openings (4) raises the valve against the base of the choke mandrel (5), thus plugging the tubing. In the form shown, a small secondary valve is incorporated in the valve (1). This secondary valve is included to permit ready equalization of pressures across the valve (1), when by-pass connections are not available at the surface, simply by lowering a weight under pressure on a Halliburton line, this weight holding the secondary valve unseated until pressures become equalized.

It is obvious that the possible application of such equipment is not limited to wells situated in coastal waters, but instead may be used to excellent advantage in any high-pressure well, and especially in flowing wells in townsites.

The differential valve mentioned is effective, of course, only insofar as flow through the tubing is concerned. It would be of no value if surface casing connections were to be broken or cut-out. To protect against this, many operators are including in their tubing strings, packers that seal the annular space between the tubing and casing. A new packer for this purpose (incidentally, a development of the removable bottom-hole choke) that affords interesting possibilities is shown in Fig. 2. This packer is run-in on the tubing, and may be unseated and pulled on the tubing. It is independent of the tubing, however, in that the tubing may be raised or lowered a short distance through it after it has been set in the casing. Slips are provided, as in a removable bottom-hole choke, to prevent well pressure from blowing the packer up the well. The packing sleeve, which packs between the packer mandrel and the well casing, is designed to be expanded by well pressure. Provision is made to prevent pressure from prematurely expanding this packing element while running the assembly into a well loaded with mud or while circulating to unload the well.

If this packer is set immediately above the producing sand, and flush-joint tubing is used from the depth at which the packer is set to the bottom of the well, it becomes possible to raise or lower the inlet of the tubing to any level of the producing zone, without changing the position of the packer and without using surface control heads. Such a feature may prove to be of benefit in those areas where the position of the tubing inlet affects the gas/oil ratio.

Drilling-in under pressure has now become a standard operation in many areas. In other areas considerable interest is being shown in its possible application. Equipment for this method of drilling-in has been thoroughly tested under a wide variety of conditions. One unusual application of this method was made recently in a high-pressure gas well near Waskom, Texas. Only a comparatively short string of 13 3/8-in. casing had been set in this well when a large volume of gas was encountered unexpectedly at a depth of approximately 4800 feet. The drill stem was blown from the well and the derrick wrecked. A new derrick was skidded over the well, and, in

order to permit installing a gate valve, large quantities of cement were pumped into the well. This cement finally bridged sufficiently to set at least partly, and to permit installing a gate valve and erecting pressure-control drilling equipment and a drilling rig.

After drilling-out of the cement was begun, it was found that only the top few feet near the surface had properly set, and that the rest was so badly gas-channeled as to permit the passage of large quantities of gas. This fact, together with the fact that the surface casing could not safely withstand heavy pump pressures, precluded the possibility of killing the well by pumping against the sand. Too, the open Blossom sand, from which large quantities of gas had been withdrawn several years previously, was later found to constitute an unlimited reservoir for "drinking up" whatever was pumped into the hole. The only possible salvation for the operators lay in drilling-out the cement and reaming to bottom under pressure. This operation, which required more than a month, was conducted without mishap against surface pressures ranging from 700 to 1050 lb. per sq. inch. Casing was eventually safely run and cemented, and the well completed.

An interesting application of pressure-control drilling equipment has been suggested for use when drilling with mud-laden fluid in high-pressure areas, and especially in those areas in which there are highly-charged shallow sands, or in which there are sections that readily absorb the drilling fluid.

The hook-up shown in Fig. 3 consists of the customary square kelly drilling head to seal the space between the kelly joint and casing, a variable choke or choke rack on the mud return line, and a pressure gauge on the mud return line between the casing and the choke rack. This gauge would be so placed as to be read easily at all times by the driller. The chokes would be so adjusted that under normal drilling conditions, the pumps running at normal speed, a pressure of, say, 25 lb. would be indicated on the pressure gauge. This pressure would, in effect, be a measure of the velocity of the mud passing through the chokes. The slightest tendency of the well to unload would be immediately indicated by an increase in the pressure shown by the gauge, whereas loss of returns would be indicated by a decrease in the gauge reading.

The suggested pressure of 25 lb. is probably high enough to afford a plus or minus reading without in itself placing the drilling head or pumps under a heavy load. The advantage that this closed method of circulating presents lies in the fact that any tendency of the well to unload or to lose circulation would be indicated much more quickly than under present open-circulating methods. It is probable, however, that the many variables that are always present in deep drilling, variation in steam pressure, mud viscosity, etc., may serve to limit the use of this method of pressure control to those operations in which these variable factors are under close observation and control.

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The development of a novel type of formation packer has greatly stimulated the use of formation packers in separating oil and gas zones. This new packer completely overcomes at least two difficulties and largely overcomes a third. In spite of the development of more nearly accurate methods of logging, the selection of the depth at which a formation packer will shut-off is still largely a hit-and-miss operation. When an ordinary formation packer has once been set, it cannot as a rule be moved to a new position without first coming out of the hole to change the length of the tail pipe beneath the packer; also, the formation on which the bottom of the tail pipe rests may not be hard enough to support the weight of the tubing for a long period of time. The new type packer is suspended on an oversize section of tubing, which extends from the packer into the casing, where it, in turn, is suspended on slips. The flow tubing extends downward through the oversize string of tubing to the packer. The flow tubing, oversize tubing, and packer are lowered to the depth at which the packer is to be set. The slips on the upper end of the oversize tubing are then set against the casing, and the weight of the flow tubing is then used to expand the packer. As no tail piece is used, there is no danger of the packer "settling."

If it develops that the desired shut-off is not obtained, provision is made for collapsing the packer and for unseating the slips, so that the packer may be raised or lowered as desired and reset in another attempt to obtain a shut-off. It is reported that one of these packers has been set nine different times without coming out of the hole.

An objection to any type of packer that is held in the expanded position by the weight of the tubing lies in the fact that this tubing often corkscrews to such an extent as to interfere with swabbing and with the running of bottom-hole chokes, pressure bombs, etc. This new method of packer suspension overcomes, at least partly, this objection because the lower end of the flow tubing is supported against cork-screwing by the oversize section of tubing.

Gun-perforating into gas areas that overlie the producing oil zone, to obtain gas for flowing the oil, has been successfully employed in several wells recently. A packer is run on the tubing to separate the oil and gas zones and the gas is admitted to the tubing at the desired rate, usually through a control member removable through the tubing on a wire line. As the packer is set in the casing, no difficulty is experienced in obtaining a shut-off. A pressure-seal packer is especially suitable, as the seat is in the casing and the weight of the tubing need not be left on the packer.

Increasing attention is being paid to operations of this sort, and there is much experimental work now in progress that indicates considerable development and improvement in methods and equipment can be expected in the near future.

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Making a rolling-weld on a pipe-line construction job

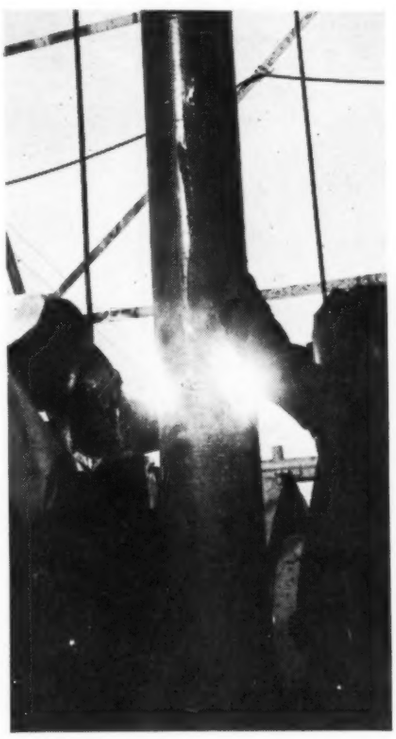
By
C. A. MULLIGAN

Progress of Welding in the Petroleum Industry

WELDING, although still in its infancy, has become a useful tool in all branches of the petroleum industry. A report of development in any year would be a comparison of the methods and uses of welding at the end of the year with its employment at the beginning of the year. Most of the fundamental principles are established, new developments being so slowly accepted that their realization could not be observed except by comparison with the previous year.

One of the greatest advances in the uses of welding during the year was in the welding of casing for oil and gas wells. Although much of this work had been done in previous years, it can be truly said that during the last 12 months its development surpassed all previous progress. A step in the advancement of casing welding was the general acceptance of the practice by the American Petroleum Institute and the appointment of a sub-committee at the annual meeting of the A.P.I. in Chicago last November. The committee made its first report of progress at the Mid-Year Meeting of the A.P.I. in Wichita, Kansas, in May. Headed by National Chairman L. R. Hodell, it mapped a program for coöperation of casing manufacturers, welding material and equipment manufacturers, welding contractors and finally, and most important, operating companies in the oil industry. The greatest development during the year was in establishing proper welding technique, training of welders, and adjustments of drilling rig operations to running of welded casing. A great step forward has been accomplished and under the guidance of the Casing Welding Committee, a definite program has been established for further development.

One of the most valuable uses of welding is in the reconditioning of pipe lines in service. Great progress has been made in this use of welding during the last 12 months, and it can now be said that once a welded oil pipe line is put into active service it is possible to keep that line in continuous service indefinitely, as reconditioning by welding does not necessitate interruption of operations. Many of the oil trunk line systems have been in service a sufficient length of time to begin to show some loss of efficiency because of leakage caused by corrosion. Extensive reconditioning work during the last 12 months has developed methods of repairing loaded lines by welding so that the lines can be returned to 100 percent efficiency without interruption of service or reduction of capacity of the lines. This, of course, assumes that a reconditioning program will be scheduled before parts of the line become damaged beyond repair. Knowing that operating efficiency can be maintained by reconditioning, pipe line company officials are in position to schedule a definite program for reconditioning a part of their lines each year after the lines reach the age when they begin to lose efficiency. The term of operation of a line before reconditioning should be scheduled is dependent upon the corrosive or otherwise destructive character of the soil and climate in which the line operates. If a line is repaired before



Welding casing

corrosion completely penetrates the pipe wall, it is possible to return the pipe to 100 percent efficiency by spot-welding all corrosion pits. Completely corroded sections can be encased in an additional tube by welding half-sections around the pipe, and on many lines this is found preferable to interruption of operation for replacement of damaged pipe.

Welded construction of oil and gas pipe lines is an established practice developed to a high degree. There have been no revolutionary developments in pipe-line welding during the last 12 months. Efforts toward improvement have been concentrated on the training of welding operators and the improvement of welding equipment and materials. There has been constant effort toward increasing the speed of welding without loss of strength or joint efficiency. Because 100 percent joint efficiency is attainable by pipe-line welding, it has been possible for engineers to design pipe lines of the minimum tonnage of steel necessary for safe operation.

A great deal of consideration has been given to gas conservation in the production of oil, both to save this fuel for future use and to maintain a reservoir pressure to insure maximum recovery from oil sands. During the last 12 months several high-pressure gas repressuring or recycling systems have been installed in new fields in which the gas produced with the oil has been returned to its original sand at pressures exceeding 3000 lb. per sq. inch. Welding has made construction of such plants an economic possibility and welded joints offer a large factor of safety at high pressure.

In the construction and operation of refineries, welding has been an established practice for many years. A refinery is incomplete without a complete welding shop, a regularly employed welding crew, or complete welding service available to the refinery from established and qualified contractors. In the past, other divisions of the petroleum industry have relied on refinery engineers and operators for information on welding design, technique, and organization. Associated refineries are still being consulted by other divisions of oil companies for welding information and welding organization, but welding of pipe lines has reached the point that refineries may well depend on their associated pipe line companies as the source of information and of qualified welding operators.

The welded joint in storage tanks and transfer lines offers positive insurance against evaporation and leakage losses. The gasoline pipe line transportation system would not be an economic engineering possibility without welding. The development of welding during the last 12 months in this branch of the petroleum industry has paralleled that of other divisions of the industry.

Summing up, welding, as a tool for construction, maintenance, and operation in all branches of the petroleum industry, has profited from a healthy growth by more general use of the process. Within a few years, welding has developed from a spectacular sideshow type of operation to a commonplace, useful necessity in the industry.

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New Directors Appointed for Houston Oil Show

At the annual meeting of the Oil-World Exposition, Inc., in Houston, Texas, recently, members approved the action of the directors in providing for the holding of the show every two years. The next show will, therefore, be held April 24 to 29, 1939, and on alternate years thereafter, with Ed G. Lenzner as general manager.

All directors of the Oil-World Exposition, Inc., except three were re-elected for another term and 76 new directors were chosen. The executive committee was increased to 11 members but the number of officers remains the same as last year. A vote of thanks was given to the officers and the executive committee for the highly successful exposition conducted by them in 1937.

Officers are: John R. Suman, president; Chase Sutton, executive vice-president; J. S. Abercrombie, vice-president; George A. Hill, jr., vice-president; W. L. Childs, vice-president; Wallace Wilson, vice-president; Ray L. Dudley, secretary-treasurer; and Ed. G. Lenzner, general manager.

The Executive Committee is composed of the following: J. S. Abercrombie, president, J. S. Abercrombie Company; S. P. Brown, vice-president, Hughes Tool Company; Frank S. Carothers, branch manager, Norvell-Wilder Supply Company; W. L. Childs, vice-president, Reed Roller Bit Company; Ray L. Dudley, president, Gulf Publishing Company; George A. Hill, jr., president, Houston Oil Company; Joe H. Russell, assistant vice-president, Gulf Oil Corporation; W. B. Sharp, president, Mission Manufacturing Company; John R. Suman, vice-president, Humble Oil and Refining Company; Chase Sutton, division manager, Pure Oil Company; and Wallace Wilson, president, Wilson Supply Company, all of Houston, Texas.

Directors are: J. S. Abercrombie, president, J. S. Abercrombie Company, Houston, Texas; R. E. Allison, R. E. Allison Drilling Company, Shreveport, Louisiana; John O'H. Anderson, manager sales, Tube Sales Department, Jones and Laughlin Steel Corporation, Pittsburgh, Pennsylvania; V. E. Ashford, district manager, Parkersburg Rig and Reel Company, Houston; F. M. Austin, superintendent commerical and industrial sales, Petroleum Electric Power Club, Houston; J. C. Axelson, Axelson Manufacturing Company, Ltd., Los Angeles, California; Thomas H. Barton, president, Lion Oil and Refining Company, El Dorado, Arkansas; Cy Bell, Bell and Loffland, Drilling Contractors, Los Angeles; H. R. Bennett, vice-president, Mills Bennett Production Company, Houston; C. N. Black, division superintendent, Magnolia Petroleum Company, Shreveport; Richard Bloss, president, International Derrick and Equipment Company of Texas, Beaumont, Texas; A. M. Blow, vice-president, Amerada Petroleum Corporation, Tulsa, Oklahoma; A. I. Brainard, president, Beaumont Iron Works, Beaumont; J. D. Brance, president, Brance-Krachy Company, Houston; R. A. Broomfield, sr., director, Barnsdall Oil Company, Los Angeles; S. P. Brown, vice-president, Hughes Tool Company, Houston; Al Buchanan, president, A. A. Buchanan Drilling Contractor, San Antonio; L. D. Cain, sales manager, Portable Rig Company, Houston; Frank S. Carothers, branch manager, Norvell-Wilder Supply Company, Houston; Frank Champion, sales manager, Oil Tool Division, Byron Jackson Company, Los Angeles; S. T. Childress, vice-president and general manager, Rio Bravo Oil Company, Houston; W. L. Childs, vice-president, Reed Roller Bit Company, Houston; H. J. Craig, sales manager, Baash-Ross Tool Company, Houston; John T. Crotty, president, Republic Supply Company, Houston; H. R. Cullen, president, Quintana Petroleum Company, Houston; W. H. Curtin, president, W. H. Curtin and Company, Houston; M. N. Dannenbaum, president, M. N. Dannenbaum Company, Houston; K. W. Davis, president, Mid-Continent Supply Company, Fort Worth; A. L. Derby, president, Derby Oil and Refining Company, Wichita, Kansas; T. J. Donoghue, vice-president, The Texas Company, Houston; Ray L. Dudley, president, Gulf Publishing Company, Houston; H. John Eastman, president, Eastman Oil Well Survey Company, Long Beach, California; E. E. Fogelson, independent producer, Houston; Julius Fohs, president, Fohs Oil Company, Houston; Allen Galloway, vice-president, Shell Petroleum Corporation, Houston; E. W. Gildart, president, Norvell-Wilder Supply Company, Beaumont; C. L. Gladden, vice-president and assistant manager production, Magnolia Petroleum Company, Dallas; A. C. Glassell, jr., oil operator, Shreveport; E. F. Goggins, president, Gulf Engineers, Inc., Houston; N. G. Guiberson, vice-president, Guiberson Corporation, Dallas; H. W. Gwilliam, vice-president, Ohio Oil Company, Houston; Harry C. Hanszen, oil operator, Houston; Dudley Hardcastle, vice-president, Spang Chalfant, Inc., Pittsburgh; R. H. Hargrove, vice-president, production and pipe lines, United

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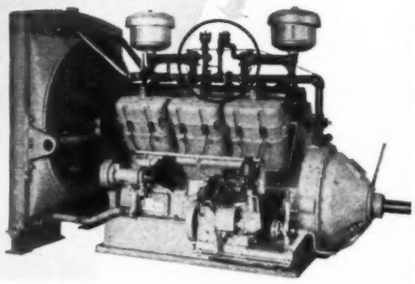

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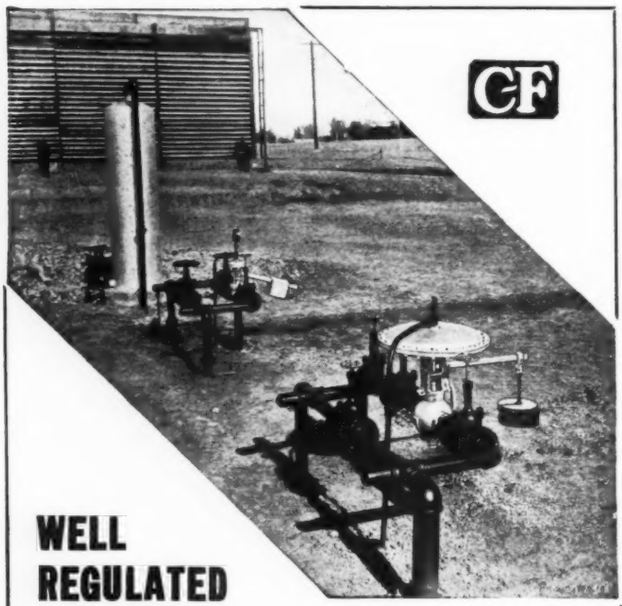

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Arthur P. Van Schaick Passes Away

Arthur P. Van Schaick, vice-president of the American Chain and Cable Company, Inc., died June 7, while traveling from New Orleans to Chicago on the Panama Limited. Following a month's vacation at Beaumont, California, Van Schaick was en route with Mrs. Van Schaick to their home at Southport, Connecticut.

As vice-president in charge of sales for the American Chain and Cable Company, Van Schaick's duties carried him to all parts of the country, and he possessed a wide acquaintance in manufacturing, wholesaling, and railroad circles. He was also a director of American Chain and Cable Company, a director of the Chain Institute, and former president of the American Hardware Manufacturers' Association.

Born in Chicago, December 29, 1882, he was the son of Mr. and Mrs. Anthony Gerard Van Schaick, and the grandson of the late Governor Harrison Ludington of Wisconsin. The family was engaged in lumbering operations in Wisconsin and Michigan, and later in the south. Mr. Van Schaick attended Asheville School, graduating in 1902, then went to Williams College. He was a trustee of Asheville School. His early business experience was with Pittsburgh Plate Glass and Lackawanna Steel. In 1919 he joined the American Chain Company at Bridgeport, Connecticut, as manager of sales. Several years later he was elected a director, and three years ago was elected vice-president in charge of sales of all divisions.

Fred A. Miller Resigns from S. R. Dresser Manufacturing Company

After more than 35 years of service, Fred A. Miller has decided to relinquish all official duties with the S. R. Dresser Manufacturing Company, Bradford, Pennsylvania. His resignation as a director and officer was accepted after a tribute by all his associates to the position of high respect in which he is held by the entire gas industry, and his valuable service to the company.

In 1905, when the S. R. Dresser Manufacturing Company was first incorporated, Miller became secretary-treasurer. Solomon R. Dresser, founder of the company in 1880, was president. Since that time, Miller has witnessed and played an important part in the tremendous growth of the gas industry in this country.

Following Dresser's death in 1911, Miller became president and served in that capacity for 18 years, until 1929, when he was elevated to chairman of the board of directors.

During his long and outstanding association with the gas and oil industry, where he is and has been widely known for years, Miller served as president of the Natural Gas Supply Men's Association until its affiliation with the American Gas Association. He later became a director of A. G. A.

As a mark of the esteem with which his associates regard him and his contribution to the company's past growth, he has been elected honorary chairman of the board by the directors of the Dresser company.

Touring Illinois and Indiana Fields

L. D. Armstrong, secretary-treasurer, and H. A. Wienecke, jr., sales engineer, Gaso Pump and Burner Manufacturing Company, Tulsa, Oklahoma, are making a tour of the Illinois and Indiana oil fields inspecting the Gaso equipment in service in that territory.

Republic Steel Appoints Enduro Distributor

N. J. Clarke, vice-president in charge of sales for Republic Steel Corporation, Cleveland, Ohio, announces the appointment of Union Hardware and Metal Company, Los Angeles, California, as a distributor of Enduro Stainless Steel.

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A. O. Smith Corporation Experimenting with Drilling and Production Equipment

For the last two years, the A. O. Smith Corporation has been carrying on some rather unusual experiments with operating equipment for the oil fields, the two principal projects consisting of drilling oil wells and pumping oil to the surface of the ground. The principles of operation of this experimental equipment are different from the methods now being used.

The first drilling experiments with this equipment were carried on at the Milwaukee plant in drilling two water wells. These wells were 15 in. in diameter and approximately 1100 ft. deep. From these experiments, the equipment was developed to a point of efficiency whereby the Smith engineers felt safe in attempting to drill in the oil fields. This well was undertaken in the West Coyote field about 20 miles east of Los Angeles about March 1, and the drilling operations were completed in approximately 30 days. This hole was 4100 ft. deep, 3200 ft. of which was 17½ in. in diameter and the remaining 900 ft. was 12 in. in diameter. The well was cased with Smith casing and placed on production.

The principle of this new equipment differs from the present-day drilling methods in that the power is applied to the drill bit at the bottom of the hole, whereas the present method of rotary drilling applies the power at the top of the hole, being transmitted through a long column of pipe to the bit itself. Further experiments are being carried on in the oil fields in drilling deeper holes with this equipment. It is stated that until these deeper holes are completed, no production plans for the manufacture of this equipment will be made.

Other points of advantage claimed for this new type of equipment, aside from its being well adapted to deep-hole drilling, is that it is of comparatively light weight, drills a straight hole, and when fully developed will reduce drilling time. A number of A. O. Smith executives and engineers are on the ground conducting these experiments.

The oil-pumping equipment being developed is unusual in that the entire mechanism is lowered to the bottom of the hole by means of a tube through which the oil is pumped. This mechanism is operated by an electric motor, and the electric current is transmitted to the motor by means of an electrical cable attached to the tubing. These pumps are sometimes placed as deep as 5000 or 6000 ft. below the surface of the ground. They must operate continuously over long periods of time without interruption. A number of these pumping units are now operating in California oil wells. The equipment provides low power and maintenance cost, it is stated. The pumps are of tubular construction, being 5¼ in. in diameter and approximately 26 ft. long. The power for the electrical motor is transmitted to the crude oil pump hydraulically under very heavy pressure.

A number of experimental units are now being made at the Milwaukee plant, but it will be some little time before the final experiments are completed.

G. S. Hinkle is Gulf Coast Manager for American Iron

In the June issue of *The Petroleum Engineer* a news story concerning the opening of American Iron and Machine Works Company branch at Harvey, Louisiana, stated that Geo. S. Hinkle, former district manager of Houston, was appointed manager of the Harvey branch. This was in error. Hinkle is and has been for some time the Gulf Coast manager for American Iron and Machine Works Company. In this capacity he will supervise the activities of the new Harvey branch.

Standards Department Formed by General Electric

To better coördinate activities in the development and application of standards both within the company and without, the General Electric Company has formed a new Standards Department. This organization will work with the various local, national, and international associations and agencies interested in standards and codes and will also promote the development of standards for use in the company's engineering and manufacturing department. The new department will be headed by L. F. Adams, who will serve as manager and assistant to vice-president E. O. Shreve. Associated with Adams will be E. B. Paxton, E. R. Anderson, H. W. Samson, and H. W. Robb.

The formation of the Standards Department centers in one organization the work formerly done by smaller groups throughout the various General Electric plants. At the same time, however, the several standardizing committees already established by the company will continue to function in the development and design of apparatus in their respective lines.

Bethlehem Launches S. S. "Esso Baltimore"

Universal interest was centered in the launching of the "Esso Baltimore" at the Sparrows Point, Maryland, plant of Bethlehem Shipbuilding Corporation recently. Mrs. Howard W. Jackson, wife of the Mayor of Baltimore, was the sponsor.

More than 400 people attended the launching and the banquet given in honor of the sponsor. Among those present, in addition to numerous Standard Oil and Bethlehem executives, were Mayor Jackson and a number of state and city officials, and many prominent business men from Baltimore and vicinity.

The "Esso Baltimore" is the 319th vessel, and 43rd tanker built at Sparrows Point. It has an overall length of 463 ft., a moulded breadth of 64 ft., and is designed to carry 106,400 bbl. of oil on a draft of 28 ft. 4 inches. Deadweight capacity is 13,000 tons and the estimated speed 13 knots. The tank space is divided into 24 compartments with pumping capacity adequate to load or unload the ship in less than 12 hours. Steam is supplied by two water-tube oil-burning boilers, and the propelling machinery consists of single-screw installation of 3500-hp. Bethlehem turbines.

International Nickel Expands Technical Field Service

A. J. Wadhams, vice-president and manager of the Development and Research Division, The International Nickel Company, Inc., has announced the establishment of a new field office in the Grant Building, Pittsburgh, Pennsylvania. The office is under the direction of H. V. Beasley, who for the last three years has been attached to the New York office.

The main function of this office will be to promote applications of nickel alloy steels and products of the Huntington Mill and stimulate interest in nickel cast irons and the use of nickel in non-ferrous alloys.

Move to Larger Quarters

The Merco Nordstrom Valve Company and the Pittsburgh Equitable Meter Company have moved into larger quarters at 2808 East 12th Street, Los Angeles, California. A new building provides more office space and expanded warehouse facilities. Larger stocks will be carried. A railroad siding permits of carload shipping and an ample platform gives convenient access for truck shipments. The location is central for oil field and gas trade shipments.

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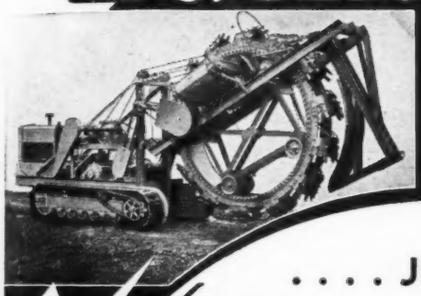

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Persistent Crew Prepares to Drill Well After Two Years in Jungle

Speaking of persistence, there's an oil-well drilling crew in the jungles of Peru that expects soon to start actual work after more than two years of preparations!

It is a "wildcat" well, located inland and six miles from the banks of the Rio Pachitea. With equipment now on hand, the crew believes it can drill to a depth of 8000 ft., hopes to tap sands that have yielded oil and gas elsewhere in South America. Although geologists say the structure looks promising, it is probable the year will end before the drill can prove its value.

The site was reached, and men and equipment moved to it, by ship, railroad, motor vehicle, airplane, river boat, and tractor—in the order named. Transportation delays and difficulties alone caused the engineers to spend two years in the jungle.

Reports indicate the heat and humidity wear down spirits and wear out shirts. There's plenty of hunting and fishing, the natives recommending monkey meat as highly palatable, and the visitors conservatively sticking to canned foods.

Natives in the vicinity of the well have proved to be good workers and able to learn quickly the use of machinery. Some already have become operators of tractors, pumping machinery, and even telephones. Seventy of them will get a daily workout chopping wood when drilling starts, steam being utilized for power, and the boilers requiring about 40 cords of wood a day.

About 18 miles from the well is the land of the Cashibos, reputedly cannibals. Reports say the Cashibos have shown no interest in oil or oil wells as yet, and that their diet is confined to members of their own tribe.

Case School to Construct New Laboratory

The Board of Trustees of Case School of Applied Science, Cleveland, Ohio, has authorized the immediate construction of the first unit of a new laboratory of chemical engineering, it is announced by President William E. Wickenden. The first unit will comprise about 40 percent of the ultimate structure.

Detail plans are now being pushed to completion by the architectural firm of Walker and Weeks and construction bids will be asked for shortly. Construction will be started this summer and the schedule calls for completion in advance of the second semester of the college year.

The building is to be of brick and steel construction. The main portion is to be 64 ft. by 100 ft. and four stories in height, with a two-story extension 45 ft. by 55 ft. to house large equipment and to provide special protection against fire or explosion risks.

Koppers Company Publishes Yearbook

The story of Koppers Company, the industrial organization that in 24 years has quietly grown to become a producer of products for nearly every type of industry in the nation, is told for the first time in "Koppers Yearbook—1938," a new book just published.

Primarily a processor of coal, the book states, the company performs all of the numerous operations necessary to obtain coke, coke oven gas, tar, light oils, and chemicals that it and other industries convert into an almost countless array of products.

Foxboro Moves Dallas Office

The Foxboro Company, makers of industrial precision instruments and controllers, have announced the change of address of their Dallas office and branch factory. The new office is now located at 1710 North Akard Street.

The entire building will be occupied by The Foxboro Company, in order to enable them to maintain a larger stock of instruments, charts, and replacement parts.

Robert H. Heyer Awarded A.S.T.M. Dudley Medal

Robert H. Heyer, junior metallurgist, Research Laboratories, The American Rolling Mill Company, has been chosen as winner of the Charles B. Dudley Medal for 1938. This medal, which commemorates the name of the first president of the American Society for Testing Materials, is awarded to the author or authors of the paper presented at the preceding annual meeting that is of outstanding merit and constitutes an original contribution on research in engineering materials. The medal was awarded to Heyer June 29 during the 41st A.S.T.M. annual meeting in Atlantic City.

The paper that won for Heyer the Dudley Medal is entitled, "Analysis of the Brinell Hardness Test," and is based on a thesis that he is presenting to the faculty of Purdue University in partial fulfillment of the requirements for the degree of Doctor of Philosophy, June, 1938.

D. T. Marvel Made Manager Tube Sales for Timken

The Timken Roller Bearing Company announces the appointment of David T. Marvel as manager of tube sales. He will have full charge of the sale of all forms of Timken seamless steel tubing. His headquarters will be at the main office in Canton, Ohio.

Book Reviews

A.P.I.-A.S.M.E. Code—Unfired Pressure Vessels for Petroleum Liquids and Gases. Third Edition. Published by Joint A.P.I.-A.S.M.E. Committee on Unfired Pressure Vessels, 50 West Fiftieth Street, New York, N. Y. (1938). 198 pp.

This volume includes the latest revisions and additions to the code established for the design, construction, inspection, and repair of fusion-welded, riveted, and integrally forged pressure vessels intended to contain petroleum liquids or gases. Appendixes include materials, suggested good practices, examples of computations, form of manufacturer's report of welding test, and form of inspection record. Significance of the section on inspection and repair cannot be too strongly emphasized, as failure to comply with its provisions would vitiate the efforts of the designer and fabricator to prepare equipment that could be used with safety. The book should be a useful guide for anyone making, selecting, or using this type of equipment.

Methods in Paleontology, by Charles L. Camp and G. Dallas Hanna. Published by University of California Press, Berkeley, California (1938). 153 pp. Price $2.50.

This volume describes methods of collecting, preparing, mounting, and displaying vertebrate and invertebrate fossils. The section on microfossils includes several methods of facilitating the separation and study of these organisms that may not be commonly known to petroleum geologists. Equipment and technique suitable for the examination of well samples are fully described.

L'exportation Pétrolifère de la Roumanie en 1937, by Mihail Pizanty. Published by Moniteur du Pétrole Roumain, Bucarest, Roumania (1938). 12 pp.

This pamphlet includes tables and charts showing the quantities of crude oil and refined products produced, consumed, and exported annually by Roumania between 1928 and 1937, and a brief discussion in two languages. Exports are classified by products and by country of destination. A map of the pipe lines and of the ports along the Danube to which shipments are made by water is included.

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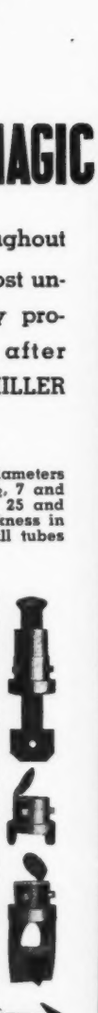

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